PB83-107441

Vegetative Delineation of Coastal Salt Marsh Boundaries: Evaluation of Methodology

(U.S.) Corvallis Environmental Research Lab., OR

Sep 82

U.S. Department of Commerce
National Technical Information Service
NTIS

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cm.)
(4-76)

EPA-600/3-82-037
September 1982

PB83-107441

VEGETATIVE DELINEATION OF COASTAL SALT MARSH BOUNDARIES: EVALUATION OF METHODOLOGY

H. Peter Eilers
Alan Taylor
William Sanville

Freshwater Division
Environmental Research Laboratory
Corvallis, Oregon 97333

ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CORVALLIS, OREGON 97333

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/3-82-037	ORD Report	PB83 107441

4. TITLE AND SUBTITLE	5. REPORT DATE
Vegetative Delineation of Coastal Salt Marsh Boundaries: Evaluation of Methodology	September 1982
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
H. Peter Eilers, Alan Taylor, William Sanville	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Environmental Research Laboratory Office of Research and Development U.S. Environmental Protection Agency Corvallis, Oregon 97333	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
same	final - inhouse
	14. SPONSORING AGENCY CODE EPA/600/02

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Legislation mandating the protection of wetlands and current pressures to convert them to other uses emphasize the need to accurately determine a wetland-upland boundary. We investigated six methods designed to establish such a boundary based on vegetation. Each method was applied to a common data set obtained from 295 quadrats along 22 transects between marsh and upland in 13 Oregon and Washington intertidal saline wetlands. The multiple occurrence, joint occurrence, and five percent methods required plant species to be classified as salt marsh, upland, and non-indicator; cluster and similarity methods required no initial classification. Close agreement between wetland-upland boundaries determined by the six methods suggests that preclassification of plants and collection of plant cover data may not be necessary to determine a defensible boundary. Examples of each method and lists of indicator plant species for coastal California, Oregon, and Washington are provided.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to public	unclassified	59
	20. SECURITY CLASS *(This page)* unclassified	22. PRICE

EPA Form 2220-1 (9-73)

NOTICE

Mention of trade names or commercial products does not consititute endorsement or recommendation for use.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.) (4-76)

ABSTRACT

Legislation mandating the protection of wetlands and current pressures to convert them to other uses emphasize the need to accurately determine a wetland-upland boundary. We investigated six methods designed to establish such a boundary based on vegetation. Each method was applied to a common data set obtained from 295 quadrats along 22 transects between marsh and upland in 13 Oregon and Washington intertidal saline wetlands. The multiple occurrence, joint occurrence, and five percent methods required plant species to be classified as salt marsh, upland, and non-indicator; cluster and similarity methods required no initial classification. Close agreement between wetland-upland boundaries determined by the six methods suggests that preclassification of plants and collection of plant cover data may not be necessary to determine a defensible boundary. Examples of each method and lists of indicator plant species for coastal California, Oregon, and Washington are provided.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
8-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cln.) (4-76)

FIGURES AND TABLES

Figure 1. Flow diagram to facilitate choice of vegetation method to determine upper limit of wetland 12

Table 1. Lower transition zone limit (LTZ) and upper limit of marsh (ULM) as determined by 6 methods applied to 22 transects from Frenkel et al. (1978). Limits expressed as distance (M) along transect where distance increases from marsh to upland 32

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
1/2"

TABLE OF CONTENTS

Abstract. iii

Figures and Tables. iv

Acknowledgements. vi

Introduction. 1

Methods for Boundary Determination. 2
- Indicator Species. 3
- Five Percent 3
- Joint Occurrence 4
- Multiple Occurrence. 4
- Cluster. 5
- Similarity ISJ and ISE 5

Lists of Indicator Species. 6

Comparison of Methods 6

Discussion and Recommendations. 7

References. 10

Table 1 11

Appendices

A. Examples of vegetation methods to determine wetland boundaries. . 13

B. Salt marsh, freshwater marsh, non-indicator, and upland plant species of the Pacific Coast. 20

C. Upper limit of marsh and lower limit of transition zone determined by 6 methods applied to 22 transects. 26

D. Sample field data sheet 49

E. Computer software available at the U.S. Environmental Protection Agency, Corvallis, Oregon. 51

BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

ACKNOWLEDGEMENTS

The refinement of indicator species lists was possible through the effort of numerous scholars: Michael G. Barbour, University of California, Davis; Lawrence C. Bliss and Roger del Moral, University of Washington; Kenton L. Chambers and LaRae Dennis-Johnson, Oregon State University; Wayne R. Ferren and Chris Onuf, University of California, Santa Barbara; Keith Macdonald, Woodward-Clyde Consultants; Robert Ornduff and Molly Whalen, University of California, Berkeley; David H. Wagner, University of Oregon; and Joy Zedler, San Diego State University. We greatly appreciate their time and effort.

We also thank Theodore Boss for comments and criticism; Jo Oshiro for help with computer graphics; and Brian Lightcap, Terry Huffman, Robert Frenkel, Porter Reid, David Peters, David Price, and William Sipple for critical review of the draft manuscript.

9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

INTRODUCTION

Two decades of intensive research following the suggestions of Odum (1961) and the work of Teal (1962) have firmly established positive values for undisturbed coastal salt marshes. These intertidal wetlands are noted for high macrophyte production and for export of energy-rich organic detritus and dissolved organic carbon to estuarine waters. They serve as juvenile fish and wildlife habitat, buffer to erosion of sediment, and potential water purifiers.

Concurrent with increased awareness of salt marsh values and potentials, however, has been the rapid conversion of coastal marsh to urban, industrial, and agricultural uses through diking, filling, and construction activities (Darnell 1976). Recent federal legislation is designed to retard these alterations and thereby protect the nation's remaining wetland resources. Most notable are the Federal Water Pollution Control Act Amendments of 1972 and 1977 (Water Act) which, in Section 404 establish a permit review process to regulate dredge and fill projects.

To implement Section 404 requires that those involved in the review process be able to: (1) identify wetland and (2) determine wetland boundaries. Yet, while wetland may be identified by noting the presence of standing water and plants adapted to saturated soil conditions, the determination of the upper limit is difficult. Instead of exhibiting a sharp break, the characteristics of wetland are more likely to gradually shift to those of upland, defined here as terrestrial non-wetland along a transition. In salt marsh, the influence of the tide diminishes with increasing surface elevation, soils become better drained, and vegetation gradually changes. An ecotone with interdigitation of marsh and upland plant species occurs between the two systems.

To better understand the nature of the marsh-upland ecotone and to develop methods of delineating a legally defensible intertidal salt marsh boundary, the U.S. Environmental Protection Agency, in conjunction with the U.S. Army Corps of Engineers, began a major research effort in 1975. After three pilot projects were completed (NOS 1975, Frenkel and Eilers 1976, Jefferson 1976), five groups were funded to investigate transition zones and upper limits. They covered salt marshes along the coasts of California (Harvey et al. 1978); Oregon and Washington (Frenkel et al. 1978); Alaska (Batten et al. 1978); Delaware, Maryland, Virginia, and North Carolina (Boon et al. 1978); and freshwater marshes along the shores of Lake Superior, Lake Michigan, and Lake Huron (Jefferson 1978). The reports provide a floristic description of marsh-upland ecotones and identify approaches to boundary determination based on vegetation.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Gin.) (4-78)

The purpose of this report is to: (1) evaluate the methods used by these researchers; (2) present alternative methods; (3) recommend the best approach to wetland boundary delineation based on vegetation; and (4) provide appropriate plant lists and computer software to apply methods to Pacific Coast salt marshes. The methods presented in this report are applicable to wetland-upland boundary determination in general, not to salt marshes alone. However, we do acknowledge that vegetation should not be the only criteria considered. The best approach will incorporate an analysis of vegetation, soil, and hydrology. The methods provided here are a first approximation, but as our knowledge of physical factors across the wetland-upland ecotone increases methods for defining boundaries will be refined. At the moment we must rely primarily on a vegetation approach.

METHODS FOR BOUNDARY DETERMINATION

The methods of determining wetland boundaries presented by the researchers listed above range from those emphasizing indicator species with little quantitative data, to those requiring classification of all plant species recorded and intensive quantitative treatment. First, we consider the less quantitative approach favored by Batten et al. (1978) and Jefferson (1978); then the more quantitative methods of other researchers. To this we add other quantitative approaches.

Indicator Species

Batten et al. (1978) investigated Alaskan coastal salt marshes and collected information on plant species percent cover from quadrats located along the elevation gradient between marsh and upland. Based on their data and knowledge of plant species habitat preference, they developed lists of indicator species that signal the shift from salt marsh to terrestrial upland or freshwater marsh. The lower limit of the transition zone (LTZ) was established at the point where species "abundant" in upland or freshwater wetland first become "abundant" in the marsh. The upper limit of marsh (ULM) was set at the point where all the species characteristic of the vegetation type bordering the marsh were present in "appropriate amounts". No definition of "abundant" or "appropriate amounts" is given and thus establishing an actual boundary in the field using this approach would be subjective and ill-suited to situations involving legal scrutiny.

Jefferson (1978) likewise developed indicator plant species lists from the study of freshwater marshes along the shores of the Great Lakes. Her treatment of the marsh-upland ecotone is comprehensive, yet little attention is given to boundary delineation. She states that "by using the community descriptions and lists of dominant, prevalent, and differential species, detection of the ecotone and its limits should be facilitated." As with Batten et al. (1978), this approach requires much subjective judgment and may be expected to yield only an approximate boundary determination.

Five Percent

The initial approach of Boon et al. (1978) and Harvey et al. (1978) was similar to those above but included boundary delineation. Following acquisition of plant cover estimates from transects along the transition from marsh to upland, a "five percent" method was used to define the upper limit of the transition zone as the point "at which the amount of ground coverage by upland plants is at least five percent and is contiguous with the upland proper" (Boon et al. 1978). The lower transition limit is defined similarly--upland plant coverage less than five percent. Both research groups classified plant species as to marsh, transition, upland (Boon et al. 1978); or marsh, upland, non-indicator (Harvey et al. 1978) and presented results graphically. Harvey and associates applied the following procedures: (1) when a five percent cover of the appropriate type (either marsh or upland) occurred in a quadrat with no trace in the adjacent, more distal quadrat, the quadrat with five percent cover was marked as the transition; (2) if the adjacent quadrat distal to the five percent cover plot had a trace of the vegetation type in question, the adjacent quadrat was marked as the transition limit; (3) if two plots in sequence had a trace of either vegetation type, the more distal quadrat was marked as the limit; (4) if the five percent cover level fell between two quadrats, the limit was located by interpolation; (5) if no overlap of upland and marsh species occurred either due to bare ground and/or cover by non-indicator species, a point midway between quadrats in which each type was represented was chosen. Appendices A and C contain examples of this and other methods described.

Joint Occurrence

After applying the five percent method, Harvey et al. (1978) sought a "quicker, easier, but equally accurate approach." Their choice was a modification of Fager's (1957) measure of joint occurrence which takes the form

$$I_{MU} = \frac{2J}{nM + nU}$$

where, for any single quadrat, J is the number of joint occurrences of marsh and upland species, nM is the number of marsh species, and nU is the number of upland species. Non-indicator species are disregarded.

Plotting I_{MU} for quadrats along a transect shows a series of zeros for pure wetland, because there are no joint occurrences, followed by a rise to a peak in the transition and a fall to zero again in pure upland. In practice, however, Harvey et al. (1978) found it difficult to interpret such a graph when natural or man-made "patchiness" was present. This problem was largely eliminated by computing a standardized index (SI) then a standardized cumulative index (SCI) for each quadrat:

$$SI_i = \frac{I_{MU_i}}{\sum_{i=1}^{n} I_{MU_i}} \text{ and } SCI_i = \sum_{i=1}^{Q} SI_i,$$

where n is the total number of quadrats and Q is the quadrat for which SCI is computed. After plotting SCI values, Harvey et al. (1978) identified the lower and upper limits of the transition as 0.5 m above the rise of the data line from the abscissa and 0.5 m above SCI = 1.0, respectively (given 1 m distance between sample quadrats or one-half the distance if greater than 1 m). Close agreement between the SCI and the five percent method transition boundaries was observed.

Multiple Occurrence

Frenkel et al. (1978) analyzed species distribution patterns to develop four categories of species--low marsh, high marsh, non-indicator, and upland--and computed a score for quadrat data collected along transects between marsh and upland. The "multiple occurrence method" (MOM) score (M) required the assignment of a weighting coefficient:

Species Type	Weighting Coefficient
Low marsh	2
High marsh	1
Upland	-2
Non-Indicator	0

The quadrat score was calculated as

$$M = \sum_{i=1}^{n} W_i C_i,$$

where W_i is the weighting coefficient for species i, C_i is cover value for species i, and n is total number of species in the quadrat sample. Cover values were after Daubenmire (1959): 0-5% = 1, 5-25% = 2, 25-50% = 3, 50-75% = 4, 75-95% = 5, 95-100% = 6. Species present but with negligible cover were disregarded.

Positive M values were interpreted as marsh, the upper limit of marsh was defined as M = 0, and M < 0 denoted upland. However, further interpretation was necessary because M values did not always descend to a single M = 0 and thereafter remain negative. Two additional cases were noted. One contained more than one M = 0 in succession, and the other with M scores alternating

above and below zero. In both cases, the portion of the transect between first and last M = 0 were considered as the transition zone and the upper limit of marsh was placed midway through this zone. In our interpretation of this method we have assigned the upper limit of the transition zone as the ULM, a shift agreed to by Frenkel (personal communication).

Cluster

If marsh and upland are floristically different, cluster analysis (Boesch 1977) of quadrat data collected along transects between the two systems might be used to identify wetland limits. Such an approach would have the advantage of not requiring preclassification of plant species into "marsh," "upland," "non-indicator." We chose the Bray-Curtis dissimilarity measure (Clifford and Stephenson 1975),

$$Djk = \frac{\sum_{i=1}^{n} x_{ij} - x_{ik}}{\sum_{i=1}^{n} (x_{ij} + x_{ik})},$$

where x is cover value for species i in quadrats j and k, and n is the total number of species. A "flexible" fusion strategy with Beta = -0.25 (Boesch 1977) was utilized. The end product is a dendrogram showing quadrat clusters which form at decreasing levels of dissimilarity. The upland cluster was identified as that containing the highest numbered quadrats (when quadrats were numbered from wetland to upland). The upper limit of marsh was interpreted as being half the distance on the transect between the lowest numbered member of the upland cluster and the highest numbered member of the next lowest group of quadrats. This second group was identified as "transition" if three clusters were present.

Similarity ISJ and ISE

By computing the similarity in species content of adjacent quadrat samples along a transect and graphing these values, we expected to observe a decrease in similarity at the marsh-upland border. In this case, two measures were chosen. One was Jaccard's index (Mueller-Dombois and Ellenberg 1974) which requires binary data (presence-absence):

$$ISJ = \frac{c}{a + b + c} \times 100,$$

where c is the number of species common to both quadrats, a is the number of species unique to the first quadrat, and b is the number of species unique to the second quadrat. The other was Ellenberg's (1956 in Mueller-Dombois and Ellenberg 1974) modification of Jaccard's index which accepts species quantities:

$$ISE = \frac{Mc:2}{Ma + Mb + Mc:2} \times 100.$$

Here, Mc is the sum of cover values of species common to both quadrats, Ma is the sum of the cover values of the species restricted to the first quadrat, and Mb is the corresponding sum for species restricted to a second quadrat. Species noted as present but with negligible cover were assigned a value of 0.25.

LISTS OF INDICATOR SPECIES

Lists of indicator species for California, Oregon, and Washington coastal marshes are found in Appendix B. They represent a consensus of EPA researchers and local authorities. Tentative plant lists were sent to recognized authorities in botany and wetland ecology for review (see Acknowledgements) and adjustments based on their comments were made. A more complete treatment of the list compilation process including instructions to the reviewers accompanies Appendix B. Although lists are still evolving, they provide a good approximation. Also, the U.S. Fish and Wildlife Service is now compiling a nationwide list of wetland plant species through the National Wetlands Inventory program.

COMPARISON OF METHODS

To compare the results obtained by the quantitative methods presented above (excluding the indicator species method), each method was applied to a common data set. Twenty-two transects (12%) were chosen at random from the 190 sampled by Frenkel et al. (1978). The data were collected from 50 x 50 cm quadrats. Transects were located with one end well into wetland, the other well into upland, and the orientation parallel to the elevation gradient. Plant species in each quadrat were recorded as to cover class (Daubenmire 1959) except that those with negligible cover were assigned "present" status only. As LTZ and ULM were calculated by each method, careful note was made of the time involved and ease of application. We concentrated our efforts on comparison of ULM identification because of its direct relationship to jurisdictional questions. The ULM was considered to be synonymous with the upper limit of the transition zone and thus the true limit of wetland.

Data presented in Table 1 and Appendix C reveal close agreement in LTZ and ULM positions obtained by the six methods. ULM for 2 transects (0808 and 1606) was not identified by all methods, suggesting that the transects did not extend far enough to include both marsh and upland quadrats. ULM location agreed within 1.0 m on 9 of the remaining 20 transects (45%) and within 2.5 m on 13 transects (65%). The range of ULM estimates was greatest for transect

1703 (25.5 m), but cluster and similarity plots for this transect show discontinuities at positions in agreement with other methods that could be interpreted as ULM. In general, methods with species classification built in (five percent, joint occurrence, and multiple occurrence) exhibit low intra-group variability, as do those without species classification.

All methods, with the exception of cluster, involve simple calculations that can be done by hand. Cluster requires a computer. Little time difference was involved in applying each method given basic field data and plant classifications, so that the choice of method should be attuned to time available for field work and the availability of a list of indicator species.

Perhaps the most important result of this comparative treatment is that use of species presence-absence yields ULM positions identical or nearly identical to those requiring species percent cover. Thus, the extended field effort required to obtain plant cover is not necessary and the greatest return for time spent might be expected from utilizing species occurrence only.

DISCUSSION AND RECOMMENDATIONS

The above methods fall into two basic groups. The first comprises five percent, joint occurrence, and multiple occurrence and is characterized by reliance on pre-established lists of wetland and upland indicator species. A consensus of ecological thought as it pertains to plant species is built into these methods. The field researcher must have botanical expertise but, theoretically, a valid ULM determination could be made without in-depth knowledge of wetland ecology. The researcher should realize, however, that results from all methods reviewed must remain valid under evaluation by wetland specialists.

The second group--cluster, similarity ISJ and similarity ISE--does not require preclassification of plant species. Instead, it is assumed that species are distributed along transects in such a way as to form groups characteristic of wetland, transition, and upland, and that these groups can be identified objectively. This study suggests that this approach is viable and that results are comparable to those obtained by preclassification methods. Cluster and similarity methods are very sophisticated and their application by inexperienced users should be done with caution. Transect 1703 (Table 1, Appendix C) illustrates this point. A ULM of 31.5 m is suggested by strict adherence to procedure, but it is likely that a position closer to 7.0 m as indicated by five percent, joint occurrence, and multiple occurrence would have been the selected ULM, given on-site review by trained personnel. All six methods should be viewed as tools with strong indicator value and whether classification of plant species is involved or not, the final boundary decision should involve the judgment of trained personnel.

A general vegetative approach to wetland boundary identification is outlined in Figure 1. If classification of plants is available, the joint occurrence method is best because it reduces field time and yields results close to the five percent and multiple occurrence methods. If accepted plant classifications are unavailable, as is the present case for most freshwater wetlands, the cluster method or similarity ISJ applied to presence-absence

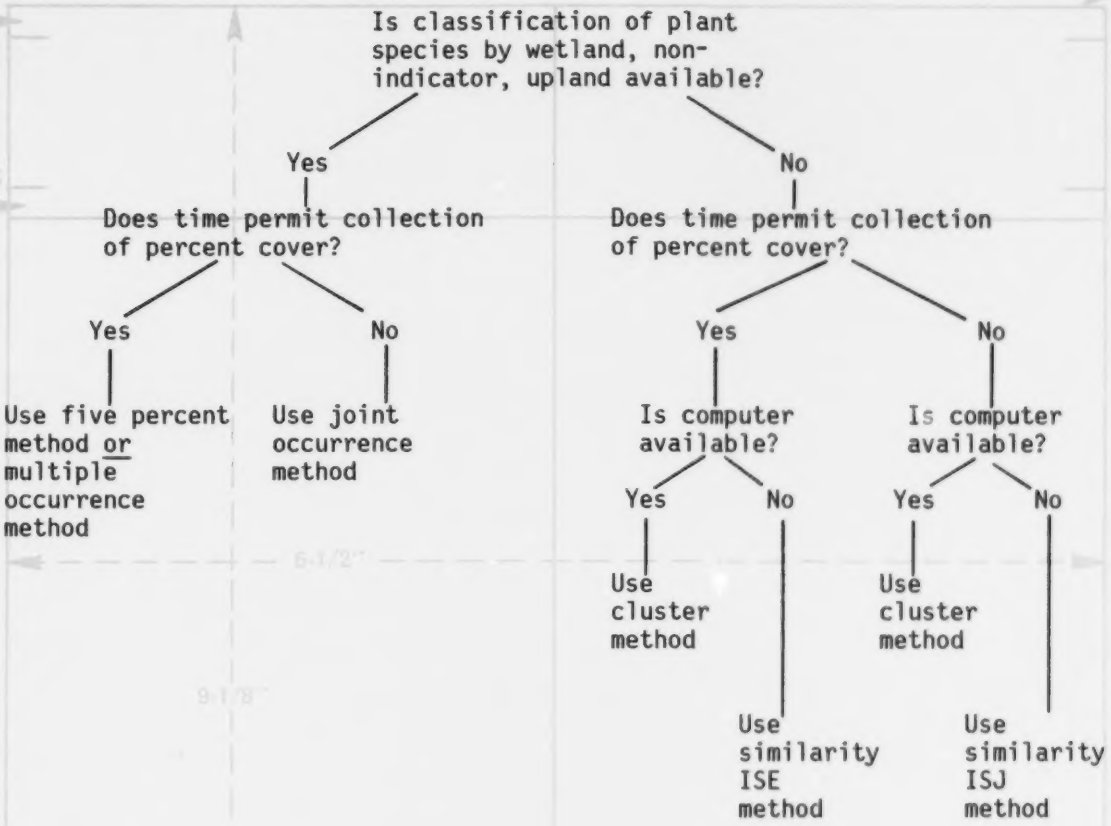


Figure 1. Flow diagram to facilitate choice of vegetation method to determine upper limit of wetland.

data provide defensible boundaries and have the added advantage of helping to establish a classification. Cluster and similarity methods are sensitive to zonal vegetation patterns but, to reiterate, it is the task of trained personnel to interpret results to obtain the ULM. Even if the requisite information needed to apply the joint occurrence method is available, it is still advisable to employ either cluster or similarity ISJ or both to support the initial decision.

Although a vegetative approach to ULM determination is likely to be satisfactory in that plant distributions reflect environmental conditions, our present knowledge of physical factors, such as soils and hydrological regimes, across the transition is very limited. It is assumed that certain plants indicate physical conditions of wetland, transition, and upland, but we do not know tolerance limits for species so classified. Research underway at the U.S. Environmental Protection Agency and U.S. Army Corps of Engineers is designed to provide a more holistic treatment of the wetland boundary problem. Physical factors between wetland and upland are being intensively monitored at

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6 1/2"
9 1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-78)

numerous wetland sites; greenhouse studies are testing species tolerance to various field conditions, such as inundation and soil saturation, and methods are being devised to incorporate both vegetation and physical factors in wetland boundary identification. In the near future, the ability to establish boundaries will be enhanced beyond the tenuous reliance on vegetation indicators alone.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

REFERENCES

Batten, A. R., S. Murphy, and D. F. Murray. 1978. Definition of Alaskan wetlands by floristic criteria. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollution. Special Scientific Report No. 77, Virginia Institute of Marine Science.

Boon, J. D., D. M. Ware, and G. M. Silberhorn. 1978. Survey of vegetation and elevational relationships within coastal marsh transition zones in the central Atlantic coastal region. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Clifford, H. T. and W. Stephenson. 1975. An introduction to numerical classification. Academic Press, New York.

Darnell, R. M. 1976. Impacts of construction activities in wetlands of the United States. U.S. EPA, Corvallis, Oregon. Publ. No. EPA-600/3-76-045.

Daubenmire, R. F. 1959. Canopy coverage method of vegetation analysis. Northwest Sci. 33:43-64.

Fager, E. W. 1957. Determination and analysis of recurrent groups. Ecology 38:586-595.

Frenkel, R. E. and H. P. Eilers. 1976. Tidal datums and characteristics of the upper limits of coastal marshes in selected Oregon estuaries. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Frenkel, R. E., T. Boss, and S. R. Schuller. 1978. Transition zone vegetation between intertidal marsh and upland in Oregon and Washington. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Harvey, H. T., M. J. Kutilek, and K. M. DiVittorio. 1978. Determination of transition zone limits in coastal California wetlands. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Hitchcock, A. S. 1950. Manual of the grasses of the United States. U.S. Department of Agriculture Misc. Publ. No. 200.

Hitchcock, C. L. and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-75)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Jefferson, C. A. 1976. Relationship of vegetation and elevation at upper and lower limits of the transition zone between wetland and upland in Oregon's estuaries. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Jefferson, C. A. 1978. Vegetative delineation of the upper limit of coastal wetlands of the upper Great Lakes. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley, New York.

Munz, P. A. and D. D. Keck. 1963. A California flora with supplement, 1968. University of California Press, Berkeley.

National Ocean Survey (NOAA). 1975. The relationship between the upper limit of control marshes and tidal datums. Rockville, National Ocean Survey report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Odum, E. P. 1961. The role of tidal marshes in estuarine production. The Conservationist 15:12-13.

Teal, J. M. 1962. Energy flow in the salt marsh ecosystem of Georgia. Ecology 43:614-624.

9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN LAST LINE OF TEXT
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD: BEGIN SECTIONS HERE
EPA-257 (Cin.) (4-76)
3/8
TYPING GUIDE SHEET
CENTER
PAGE NUMBER 12
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
TOP OF IMAGE AREA

Table 1. Lower transition zone limit (LTZ) and upper limit of marsh (ULM) as determined by 6 methods applied to 22 transects from Frenkel et al. (1978). Limits expressed as distance (m) along transect where distance increases from marsh to upland.

Transect Number	Location	Five Percent		Joint Occurrence		Multiple Occurrence		Cluster		Similarity ISJ		Similarity ISE		ULM Mean	ULM S.D.	ULM Range
		LTZ	ULM	LTZ	ULM	LTZ	ULM	LTZ	ULM	LTZ	ULM	LTZ	ULM			
	OREGON															
0105	Coquille Estuary	11.0	14.5	9.0	14.5	11.5	13.0	9.0	14.5	11.5	15.5	12.5	14.5	14.4	0.8	2.5
0208	Coos Bay	16.5	19.5	16.5	21.5	---	21.0	---	19.5	---	21.5	---	21.5	20.8	1.0	2.0
0301	Alsea Bay	9.0	15.5	---	15.5	10.0	15.0	9.0	15.5	9.0	15.5	9.0	15.5	15.4	0.2	0.5
0310	Alsea Bay	---	13.0	---	13.5	10.0	12.0	9.0	13.5	7.0	13.5	9.0	13.5	13.2	0.6	1.5
0402	Yaquina Bay	---	19.5	---	19.5	---	18.5	13.5	19.5	13.5	19.5	13.5	19.5	19.3	0.4	1.0
0407	Yaquina Bay	4.5	19.5	4.5	19.5	7.5	19.5	1.5	19.5	10.5	19.5	10.5	19.5	19.5	0.0	0.0
0704	Nehalem Bay	1.0	11.0	1.0	11.5	---	8.0	7.0	15.5	---	9.0	---	9.0	10.7	2.7	7.5
0706	Nehalem Bay	10.5	13.0	10.5	13.5	10.5	11.1	10.5	15.5	7.0	16.5	12.5	16.5	14.4	2.2	5.4
0710	Nehalem Bay	---	16.0	---	15.5	---	15.0	---	15.5	---	15.5	---	15.5	15.5	0.3	1.0
	WASHINGTON															
0804	Willapa Bay	14.5	15.5	14.5	16.5	11.0	15.0	9.0	15.5	9.0	15.5	9.0	15.5	15.6	0.5	1.5
0808	Willapa Bay	---	---	---	---	8.0	---	5.0	15.5	---	---	---	---	---	---	---
0809	Willapa Bay	15.0	22.5	---	22.5	15.0	22.0	19.0	22.5	20.5	22.5	19.0	22.5	22.4	0.2	0.5
0910	Willapa Bay	84.5	87.5	---	87.5	63.5	87.5	---	87.5	65.0	87.5	65.0	87.5	87.5	0.0	0.0
1001	Willapa Bay	256.0	265.0	---	265.0	248.0	259.0	---	259.0	---	249.0	---	249.0	257.7	7.2	16.0
1103	Grays Harbor	105.5	146.0	105.5	147.5	117.5	129.5	117.5	147.5	117.5	147.5	98.0	147.5	144.3	7.3	18.0
1201	Grays Harbor	18.5	19.5	---	19.5	---	19.0	17.0	19.5	17.0	19.5	17.0	19.5	19.4	0.2	0.5
1606	Thorndyke Bay	---	---	---	---	---	---	---	---	---	10.5	---	10.5	---	---	---
1610	Thorndyke Bay	---	6.0	3.5	7.5	---	3.0	---	10.5	---	10.5	---	10.5	8.0	3.1	7.5
1611	Thorndyke Bay	9.0	12.5	---	12.5	6.0	12.0	---	10.5	4.5	10.5	4.5	10.5	11.4	1.0	2.0
1612	Thorndyke Bay	---	21.5	---	21.5	1.0	20.0	12.0	23.5	---	12.0	12.0	23.5	20.3	4.3	11.5
1703	Snohomish Estuary	---	7.5	---	7.5	---	6.0	---	31.5	---	31.5	---	31.5	19.3	13.4	25.5
1802	Oak Bay	---	26.0	---	25.5	---	25.5	---	25.5	10.5	25.5	19.5	25.5	25.6	0.2	0.5

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.) (4-76)

APPENDIX A

Examples of Vegetative Methods to Determine Wetland Boundaries

JOINT OCCURRENCE

Field data collection
- *Quadrats at regular intervals (i.e., 1 m) along transects between marsh and upland
- *Record all plants occurring in quadrats

↓

Classification of plants recorded as to
- *Marsh species
- *Non-indicator
- *Upland species

↓

Compute joint occurrence score for each quadrat

↓

Compute Standardized Cumulative Index for quadrats

↓

Plot Standardized Cumulative Index against distance along transect

↓

Locate LTZ and ULM
- *LTZ is one half quadrat interval on transect above (toward upland) quadrat where SCI initially > 0
- *ULM is one half quadrat interval on transect above (toward upland) quadrat where SCI initially = 1.00

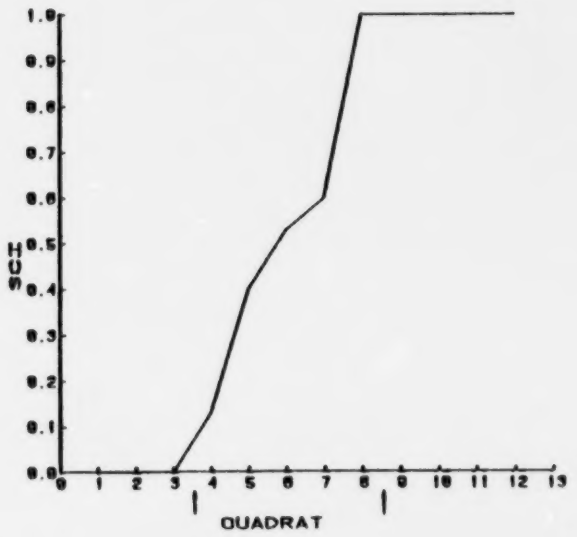
CALCULATION FOR QUADRAT 5:

Species	Classification
A	marsh
B	non-indicator
C	marsh
D	marsh
E	non-indicator
F	marsh
G	upland

$$I_{MU} = \frac{2J}{nM + nU} = \frac{2}{5} = .40$$

TRANSECT SUMMARY:

Quadrat	I_{MU}	SI	SCI
1	0	0	0
2	0	0	0
3	0	0	0
4	.20	.13	.13
5	.40	.27	.40
6	.20	.13	.53
7	.10	.07	.60
8	.60	.40	1.00
9	0	0	1.00
10	0	0	1.00
11	0	0	1.00
12	0	0	1.00



MULTIPLE OCCURRENCE

Field data collection
- *Quadrats at regular intervals (i.e., 1 m) along transects between marsh and upland
- *Record all plants occurring in quadrats and assign cover class value to each species in each quadrat

↓

Classify plants recorded as to
- *Marsh species (high or low)
- *Non-indicator
- *Upland species

↓

Compute M score for each quadrat

↓

Plot M score against distance along transect

↓

Locate LTZ and ULM
- *LTZ is first M = 0 (if > 1 M = 0) on transect from wetland to upland
- *ULM is last or only M = 0 on transect from wetland to upland

CALCULATION FOR QUADRAT 5:

Species	Classification	Weight	Cover Class**
A	marsh (low)***	2	3
B	non-indicator	0	2
C	marsh (low)	2	2
D	marsh (low)	2	1
E	non-indicator	0	2
F	marsh (high)	1	2
G	upland	-2	2

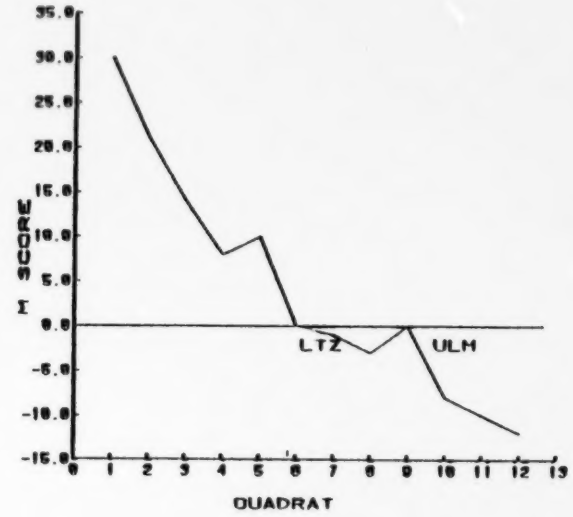
$$M = \sum_{i=1}^{n} W_i C_i$$

$$= (2x3)+(0x2)+(2x2)+(2x1)+(0x2)+(1x2)+(-2x2)$$

$$= 10$$

TRANSECT SUMMARY

Quadrat	M
1	30
2	21
3	14
4	8
5	10
6	0
7	-1
8	-3
9	0
10	-8
11	-10
12	-12



** Frenkel et al (1978) used cover class, but we recommend using percent cover rather than class.

***We recommend assignment of a weight of 2 to all plants classified as marsh.

FIVE PERCENT

Field data collection
- *Quadrats at regular intervals (i.e., 1 m) along transects between marsh and upland
- *Record all plants occurring in quadrats and assign percent cover (nearest 5%) to each species in each quadrat

↓

Classify plants recorded as to
- *Marsh species
- *Non-indicator
- *Upland species

↓

Compute total percent cover of marsh species and upland species in each quadrat

↓

Plot totals for marsh and upland species against distance along transect (in bar graph form)

↓

Locate LTZ and ULM**
- *LTZ is point at which upland species = 5%
- *ULM is point at which wetland species = 5%

**See text for rules.

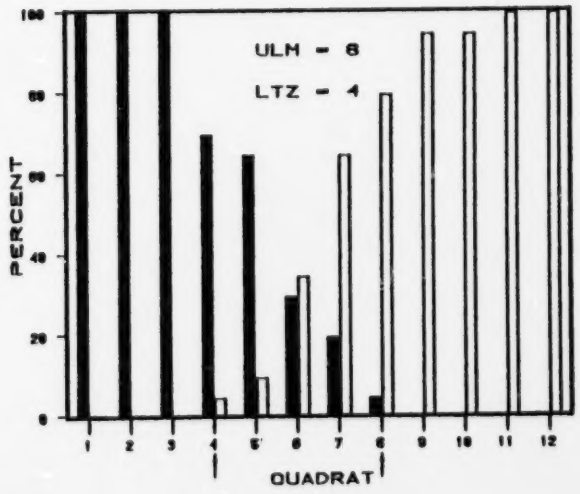
CALCULATION FOR QUADRAT 5:

Species	%Cover	Classification
A	30	marsh
B	15	non-indicator
C	20	marsh
D	5	marsh
E	10	non-indicator
F	10	marsh
G	10	upland

marsh % cover = 65
upland % cover = 10

TRANSECT SUMMARY:

Quadrat	%Marsh	%Upland
1	100	0
2	100	0
3	100	0
4	70	5
5	65	10
6	30	35
7	20	65
8	5	80
9	0	95
10	0	95
11	0	100
12	0	100



CLUSTER

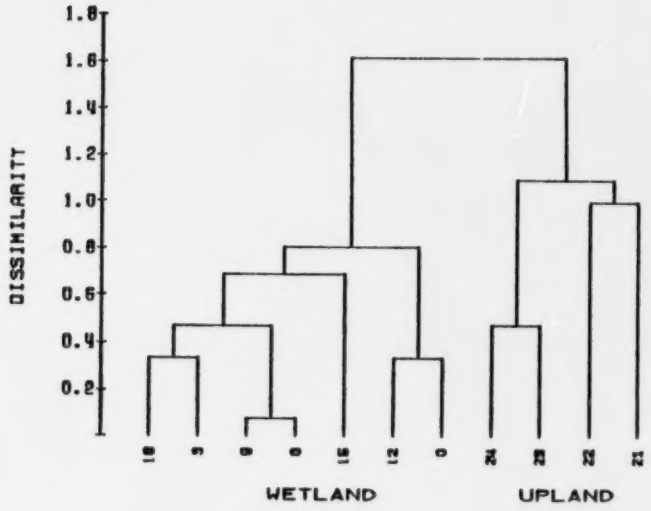
Field data collection
- *Quadrats at regular intervals (i.e., 1 m) along transects between marsh and upland
- *Record all plants occurring in quadrats and assign percent cover (nearest 5%) to each species in each quadrat**

↓

Create computer data file for each transect and run program Cluster***

↓

Locate LTZ and ULM
- *LTZ is break between wetland and transition clusters
- *ULM is break between transition and upland cluster****



** Collection of cover is optional
*** Available at EPA Corvallis
****If a transition cluster is not identified, as in this example, ULM is the break between wetland and upland and LTZ is not present.

SIMILARITY ISJ

Field data collection
- *Quadrats at regular intervals (i.e., 1 m) along transects between marsh and upland
- *Record all plant species occurring in each quadrat

↓

Compute similarity coefficient ISJ for all adjacent quadrat pairs along transect

↓

Plot similarity values against distance along transect (values located at mid-point between quadrats)

↓

Locate LTZ and ULM
- *LTZ is the first point of low similarity on transect below ULM
- *ULM is point of low similarity on transect closest to upland

CLASSIFICATION FOR QUADRATS 5 AND 6:

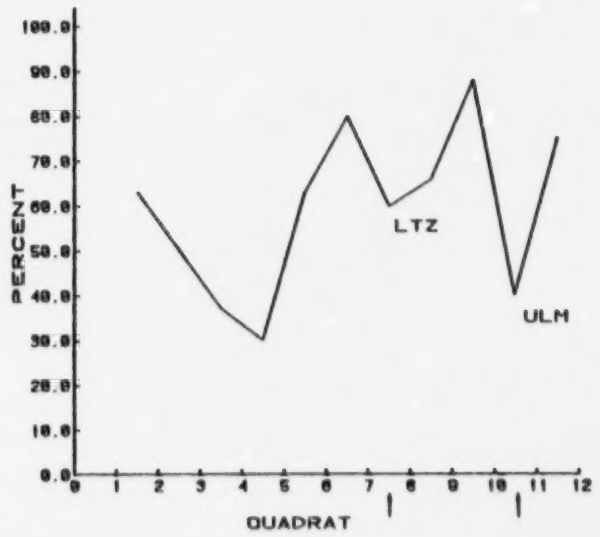
Species	Quadrat 5	Quadrat 6
A	x	x
B	x	x
C	x	x
D	x	x
E	x	x
F	x	x
G	x	
H	x	x
I	x	
J		x
K	x	

TRANSECT SUMMARY:

Quadrats	ISJ
1 & 2	63
2 & 3	50
3 & 4	37
4 & 5	30
5 & 6	63
6 & 7	80
7 & 8	60
8 & 9	66
9 & 10	88
10 & 11	40
11 & 12	75

$$ISJ = \frac{c}{a+b+c} \times 100 = \frac{7}{3+1+7} \times 100$$

$$= \frac{7}{11} \times 100 = 63$$



SIMILARITY ISE

Field data collection
- *Quadrats at regular intervals (i.e., 1 m) along transects between marsh and upland
- *Record all plant species occurring in quadrats and assign percent cover (nearest 5%) to each species in each quadrat

↓

Compute similarity coefficient ISE for all adjacent quadrat pairs along transect

↓

Plot similarity values against distance along transect (values located at mid-point between quadrats)

↓

Locate LTZ and ULM
- *LTZ is the first point of low similarity on transect below ULM
- *ULM is point of low similarity on transect closest to upland

CALCULATION FOR QUADRATS 5 AND 6:

Species	Quadrat 5	Quadrat 6
A	.25	5.00
B	5.00	5.00
C	35.00	35.00
D	5.00	.25
E	5.00	.25
F	35.00	15.00
G	5.00	
H	5.00	15.00
I	15.00	
J		.25
K	5.00	
	115.25	75.75

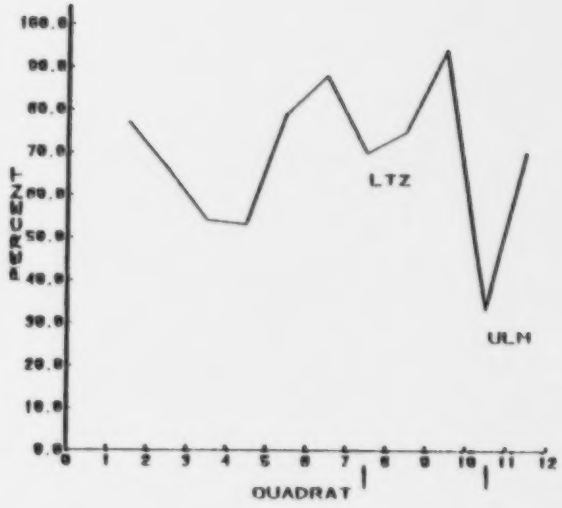
$$ISE = \frac{Mc:2}{Ma+Mb+Mc:2} \times 100$$

$$= \frac{191:2}{25+.25+191:2} \times 100$$

$$= \frac{95.5}{120.75} \times 100 = 79$$

TRANSECT SUMMARY:

Quadrats	ISE
1 & 2	77
2 & 3	66
3 & 4	54
4 & 5	53
5 & 6	79
6 & 7	88
7 & 8	70
8 & 9	75
9 & 10	94
10 & 11	33
11 & 12	40



APPENDIX B

Salt Marsh, Freshwater Marsh, Non-Indicator, and Upland Plant Species of the Pacific Coast

The lists of plant species which follow represent a consensus of EPA researchers and local authorities. Tentative plant lists from Frenkel et al. (1978) and Harvey et al. (1978) were sent to the botanists and wetland ecologists cited earlier under Acknowledgements. The following instructions were provided:

> The Environmental Protection Agency is in the process of developing a field manual, to be utilized by the Corps of Engineers and other government personnel, to determine the upper boundary of salt marshes along the California, Oregon, and Washington coasts. The method we are developing is based on the classification of plants into one of three groups. These are: salt marsh (plants found primarily in salt marshes), non-indicator (plants which may occur in wetlands or uplands), upland (plants never found in salt marshes). The enclosed lists are based on extensive field work in intertidal salt marshes and were presented in final research grant reports to the Environmental Protection Agency. What we would like you to do is review the species classification and make comments or criticisms where appropriate. Also, feel free to make additions if you think a species has been overlooked.

Several species were added and the assignment of several others was shifted but, in general, reviewers agreed with classifications as originally provided. It should be noted that upland plant lists contain only the most commonly occurring species adjacent to salt marshes and should not be considered a complete inventory. Many species with strong salt marsh indicator value may also occur in freshwater marshes, e.g., Carex lyngbyei. The lists for salt marsh include species found primarily in salt marshes. On the California coast, salt marshes are most often directly adjacent to upland, but in Oregon and Washington, salt marsh frequently shifts to freshwater marsh then to upland. A list of freshwater marsh indicator species for coastal Oregon and Washington is provided. Combining salt marsh and freshwater marsh species into a single wetland list would make it possible to compute a wetland-upland boundary where both marsh types are present.

California

Salt Marsh Plants

Plant Species[1]	Plant Species
Atriplex patula	Plantago maritima
Batis maritima	Potentilla egedei
Cordylanthus maritimus	Salicornia bigelovii
Cuscuta salina	Salicornia virginica
Frankenia grandifolia	Spartina foliosa
Grindelia maritima	Spartina spartinae[2]
Grindelia stricta	Spergularia canadensis
Jaumea carnosa	Spergularia macrotheca
Juncus balticus	Suaeda californica
Limonium californicum	Triglochin concinnum
Monanthochloe littoralis	Triglochin maritimum
Orthocarpus castillejoides v. humboldtiensis	

[1] Nomenclature follows Munz and Keck (1963 with supplement 1968).
[2] Hitchcock (1950).

Non-Indicator Plants

Plant Species[1]	Plant Species
Atriplex watsonii	Festuca rubra
Carex barbarae	Juncus leseurii
Carex pansa	Parapholis incurva
Cressa truxillensis	Salicornia subterminalis
Distichlis spicata	Vicia sativa
Elymus triticoides	

California

Upland Plants, Page 1

Plant Species[1]	Plant Species
Abronia latifolia	Convolvulus cyclostegius
Abronia umbellata	Convolvulus soldanella
Achillea millefolium	Coreopsis gigantea
Agropyron repens	Descurainia pinnata
Ammophila arenaria	Elymus mollis
Artemisia californica	Elymus vancouverensis
Artemisia douglasiana	Erechites prenanthoides
Atriplex lentiformis	Eriogonum cinereum
Atriplex semibaccata	Eriogonum latifolium
Avena fatua	Eriophyllum staechadifolium
Baccharis pilularis	Erodium cicutarium
Beta vulgaris	Foeniculum vulgare
Brassica campestris	Franseria chamissonis
Bromus madritensis	Geranium dissectum
Bromus maritimus	Glehnia leiocarpa
Bromus mollis	Gnaphalium chilense
Bromus rigidus	Heterotheca grandiflora
Cakile edentula	Holcus lanatus
Cakile maritima	Hordeum stebbinsii
Cardionema ramosissimum	Isomeris arborea v. angustata
Centaurea melitensis	Lolium multiflorum
Cirsium arvense	Lolium perenne
Conium maculatum	Lotus purshianus

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTION HERE

California

Upland Plants, Page 2

Plant Species	Plant Species
Lotus scoparius	Rhus diversiloba
Lupinus rivularis	Rhus integrifolia
Lycium californicum	Rubus ursinus
Madia subspicata	Rumex acetosella
Malva parviflora	Silybum marianum
Melilotus albus	Solanum xantii
Melilotus indicus	Solidago spathulata
Mesembryanthemum edule	Sonchus asper
Montia perfoliata	Sonchus oleraceus
Nicotiana glauca	Stellaria media
Oenothera cheiranthifolia	Tanacetum douglasii
Picris echioides	Trifolium wormskjoldii
Plantago lanceolata	Urtica holosericea
Poa douglasii	Vicia tetrasperma
Poa scabrella	Yucca whipplei
Polygonum paronychia	

6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

Oregon, Washington

Salt Marsh Plants

Plant Species[1]	Plant Species
Atriplex patula	Puccinella pumila
Carex lyngbyei	Rumex occidentalis
Cordylanthus maritimus *	Salicornia virginica
Cuscuta salina	Scirpus americanus
Deschampsia cespitosa	Scirpus cernuus
Distichlis spicata	Scirpus maritimus
Eleocharis palustris	Spartina alterniflora
Glaux maritima	Stellaria humifusa
Grindelia integrifolia var. macrophylla	Spergularia canadensis
Jaumea carnosa	Spergularia marina
Juncus balticus	Triglochin concinnum
Lilaeopsis occidentalis	Triglochin maritimum
Orthocarpus castillejoides	Zostera nana
Plantago maritima	

[1] Nomenclature after Hitchcock and Cronquist (1973).
* Variety palustris is a candidate for Federal endangered status.

Oregon, Washington

Upland Species

Plant Species	Plant Species
Achillea millefolium	Holcus lanatus
Agropyron repens	Hypochaeris radicata
Angelica lucida	Lathyrus japonicus
Carex pansa	Lonicera involucrata
Elymus mollis	Maianthemum dilatatum
Erechtites arguta	Picea sitchensis
Festuca rubra	Plantago lanceolata
Galium aparine	Poa pratensis
Galium triflorum	Rubus ursinus
Gaultheria shallon	Trifolium wormskjoldii
Heracleum lanatum	Vicia gigantea

Oregon, Washington

Non-Indicator Plants

Plant Species	Plant Species
Agrostis alba	Potentilla pacifica
Aster subspicatus	Stellaria calycantha
Hordeum brachyantherum	

Oregon, Washington

Freshwater Marsh Plants

Plant Species	Plant Species
Carex obnupta	Scirpus microcarpus
Equisetum spp.	Scirpus validus
Oenanthe sarmentosa	

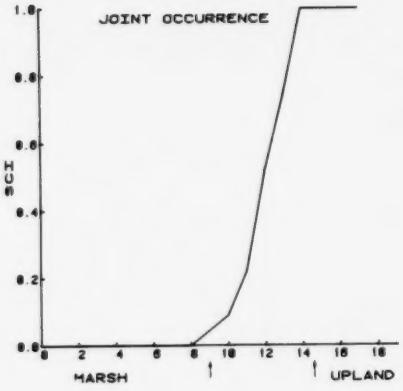
BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.) (4-76)

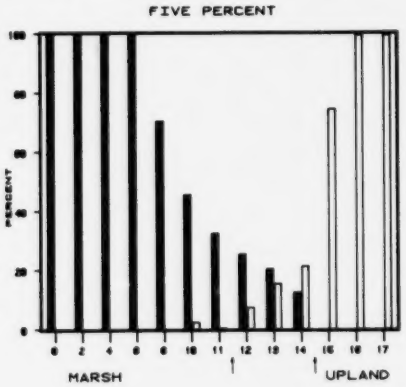
APPENDIX C

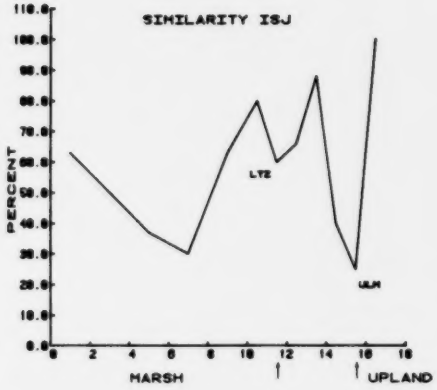
Upper Limit of Marsh (ULM) and Lower Limit of Transition Zone (LTZ) Determined by 6 Methods Applied to 22 Transects from Frenkel et al. (1978)

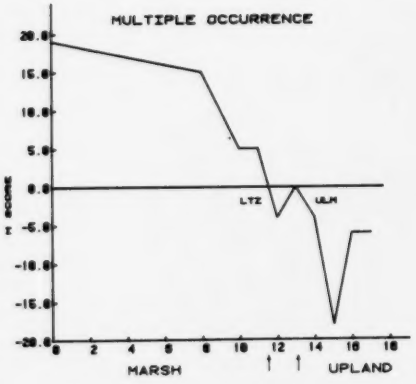
Numbers on the ordinate denote distance (m) along sample transect from wetland to upland. Arrows indicate LTZ and ULM positions listed in Table 1.

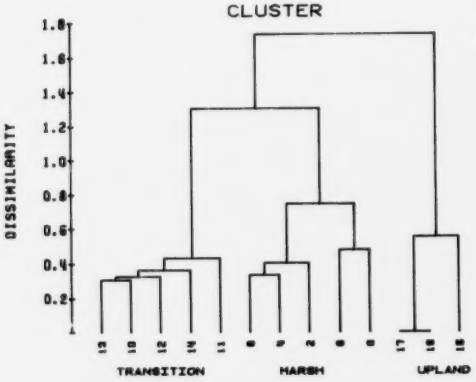
TRANSECT 0105

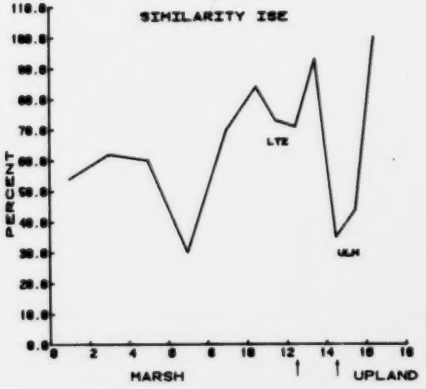




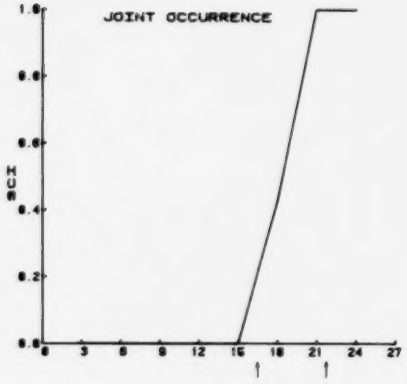


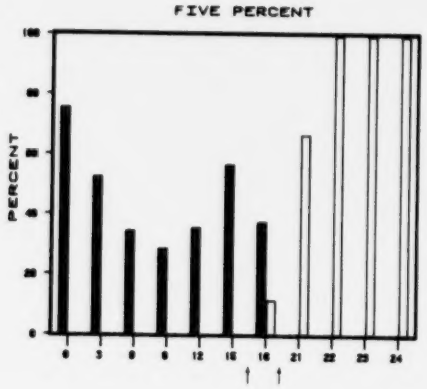


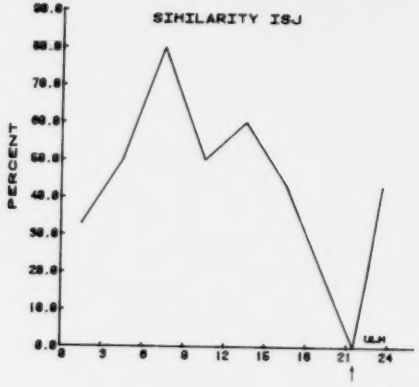


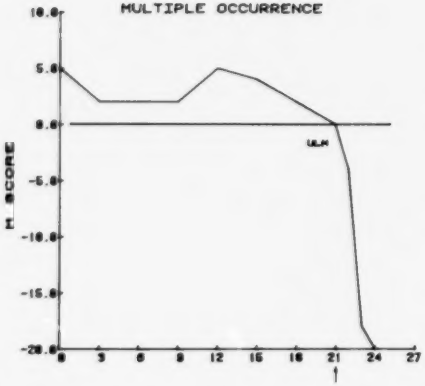


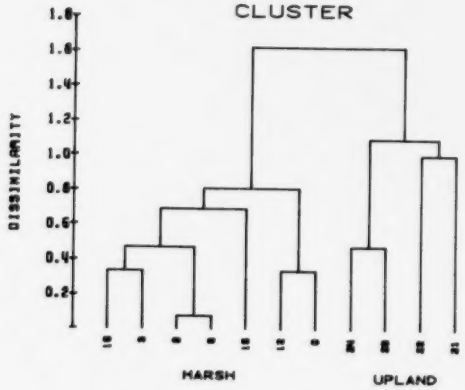
TRANSECT 0208

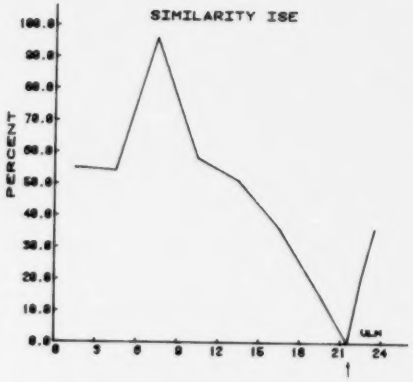




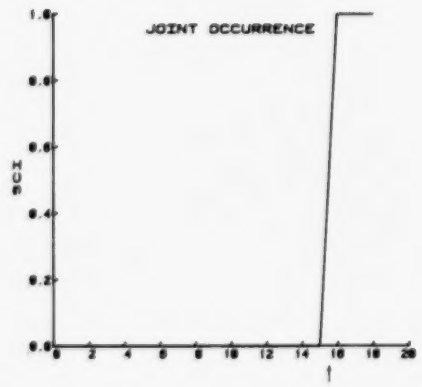


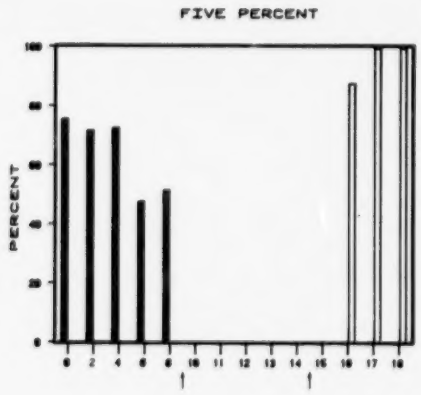


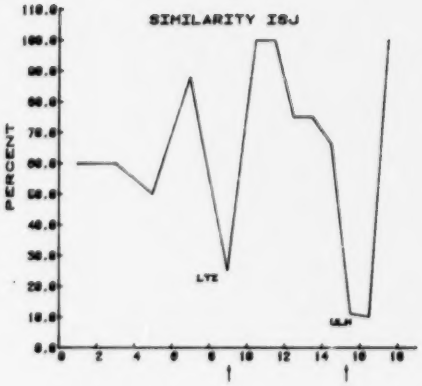


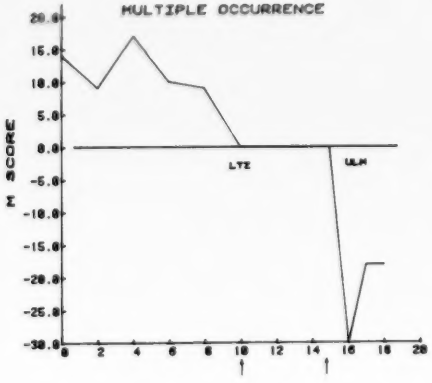


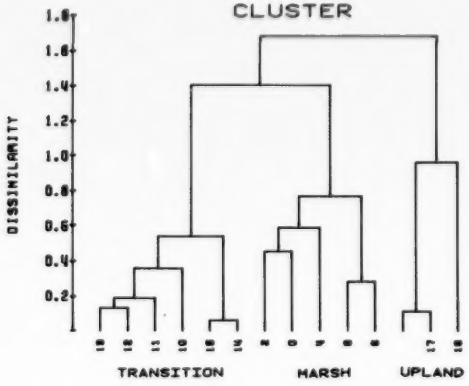
TRANSECT 0301

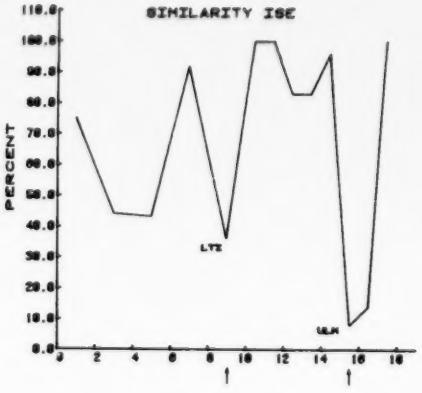




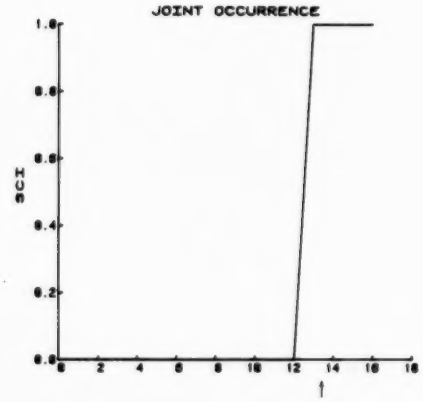


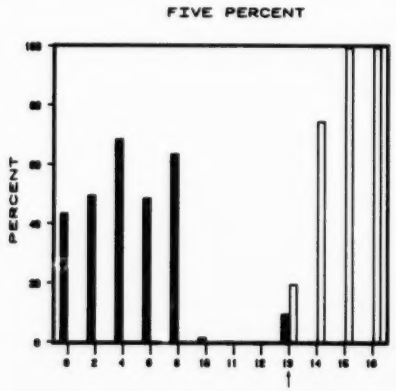


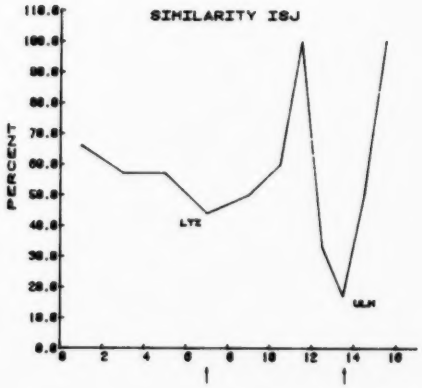


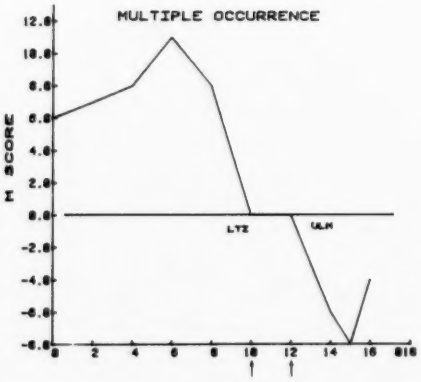


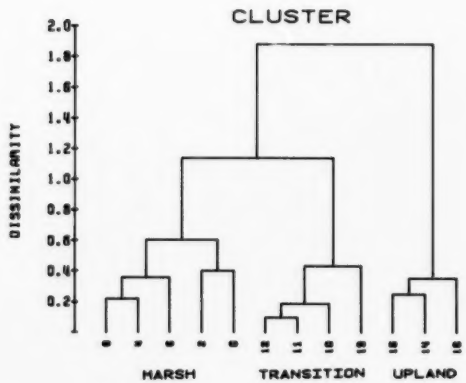
TRANSECT 0310

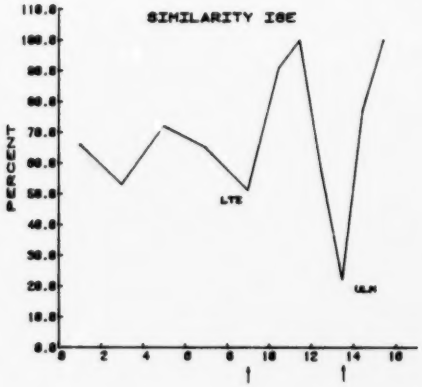




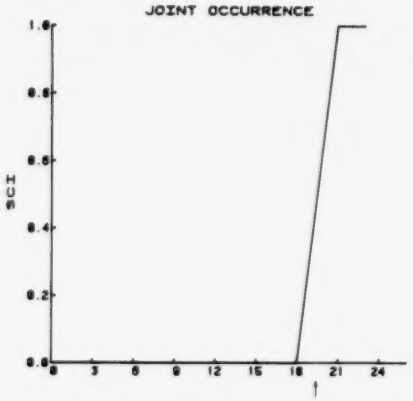


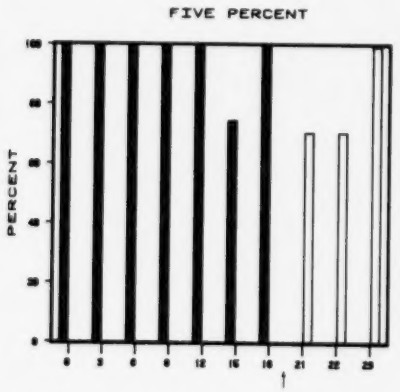


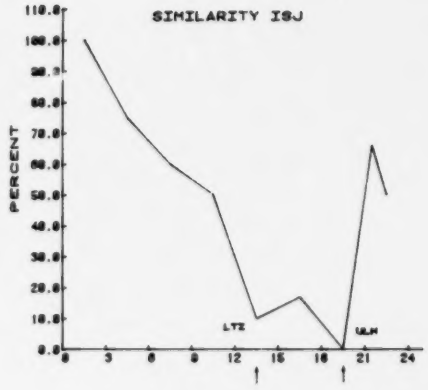


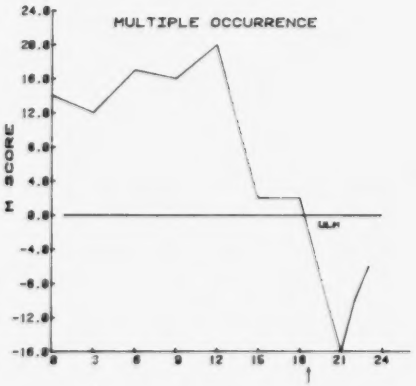


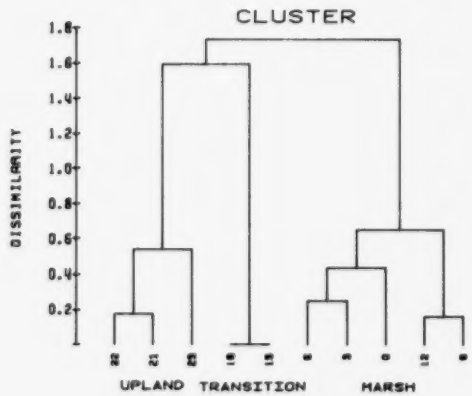
TRANSECT 0402

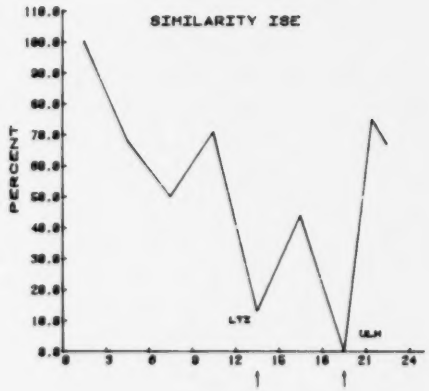




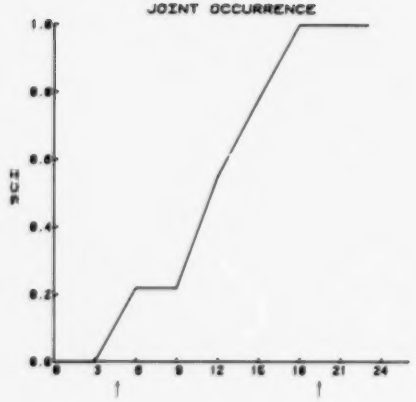


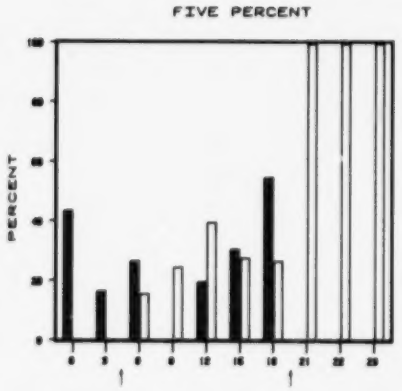


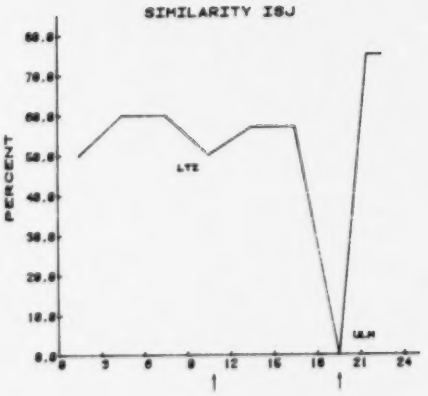


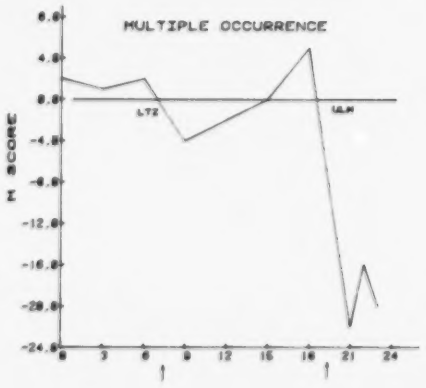


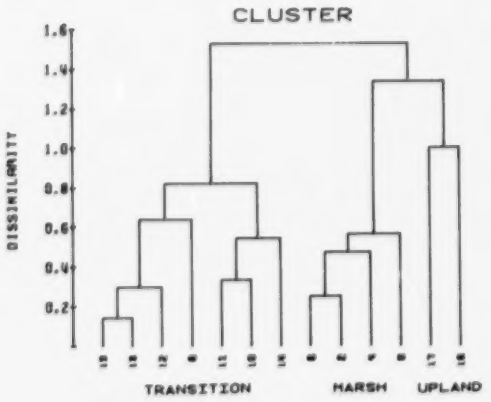
TRANSECT 0407

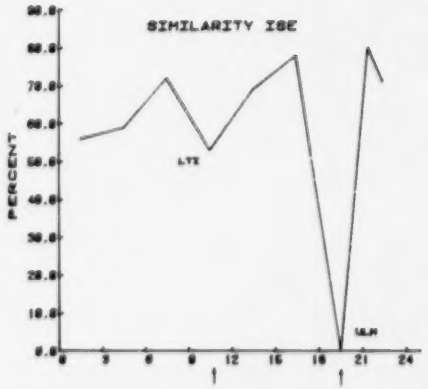




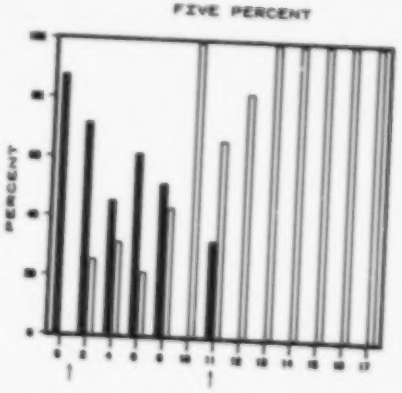


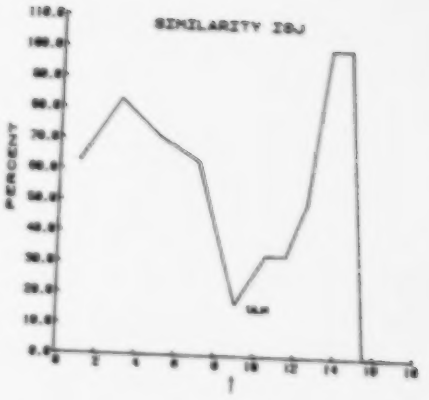


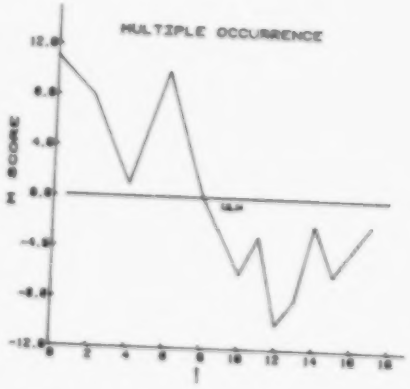


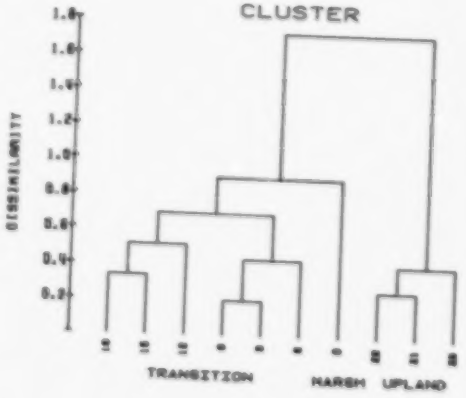


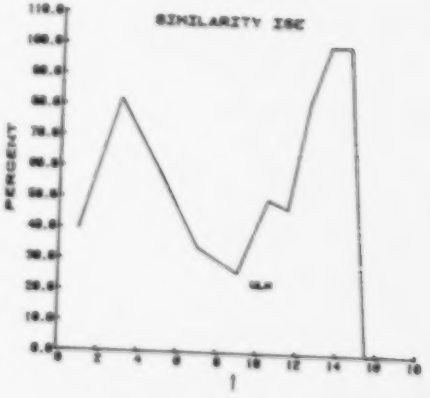
TRANSECT 0704



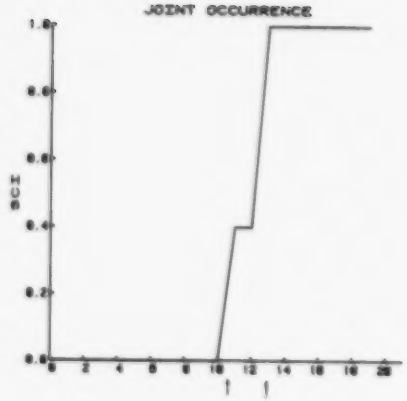


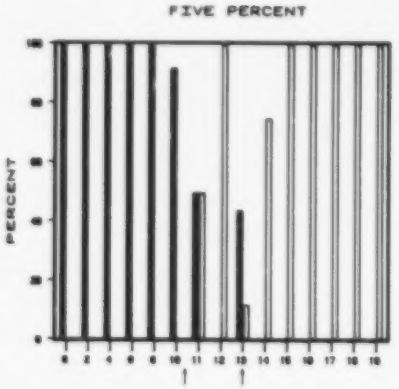


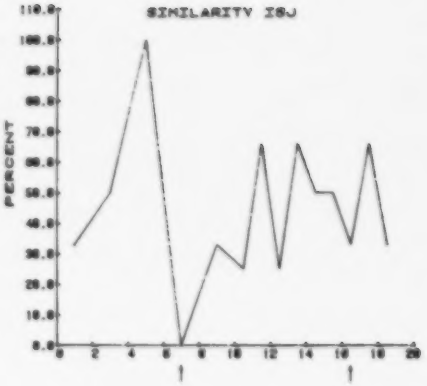


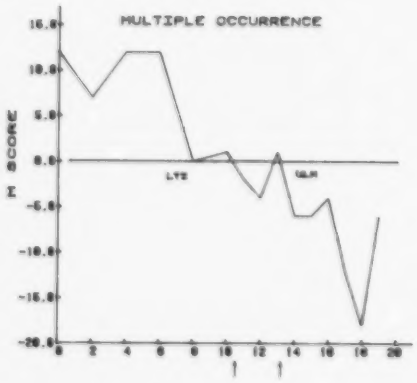


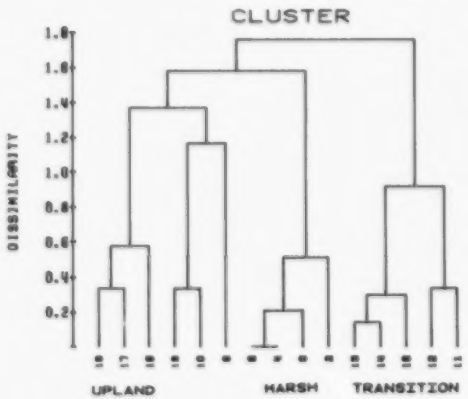
TRANSECT 0706

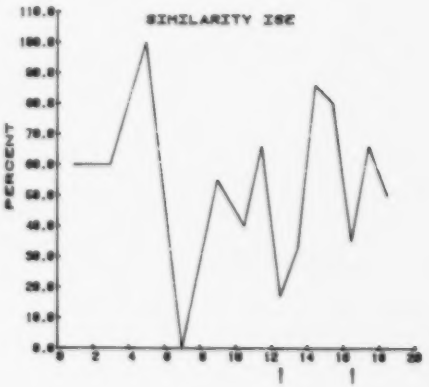




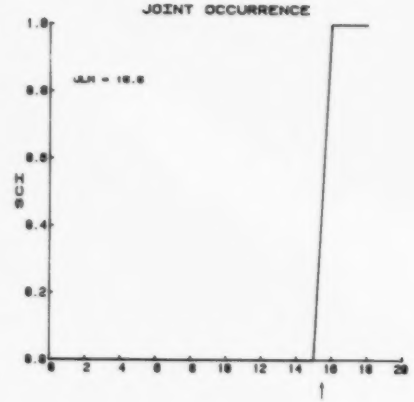


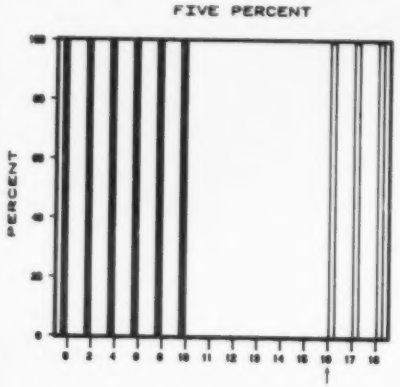


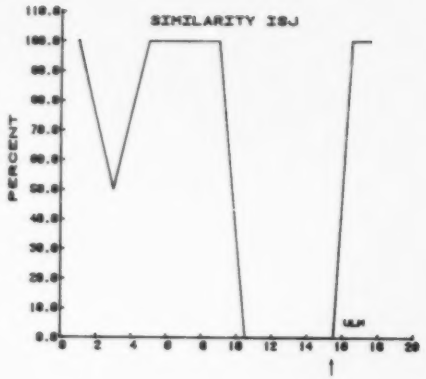


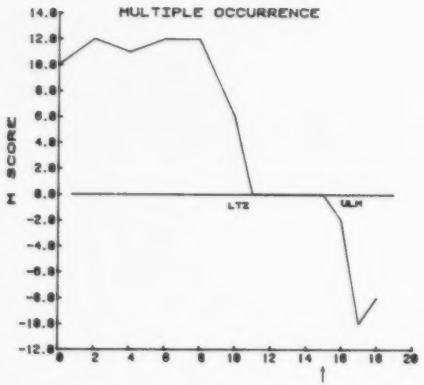


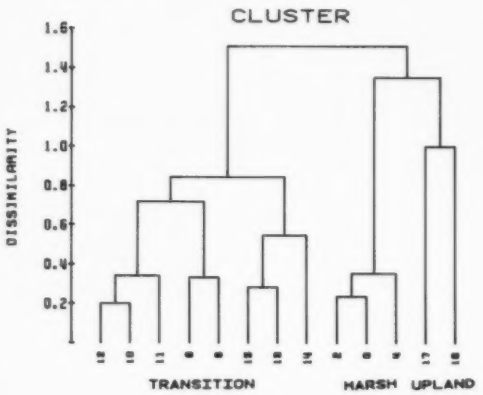
TRANSECT 0710

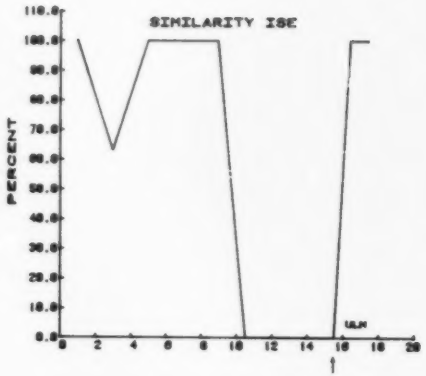




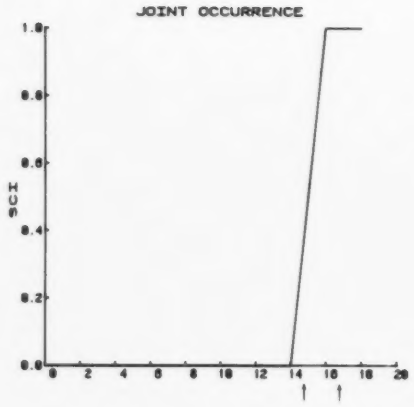


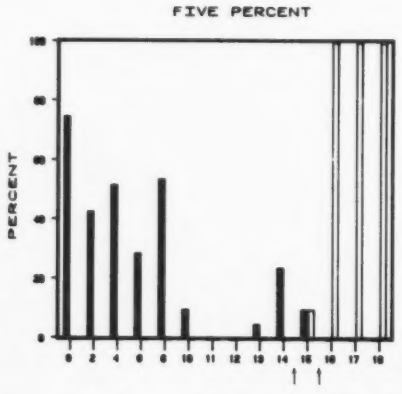


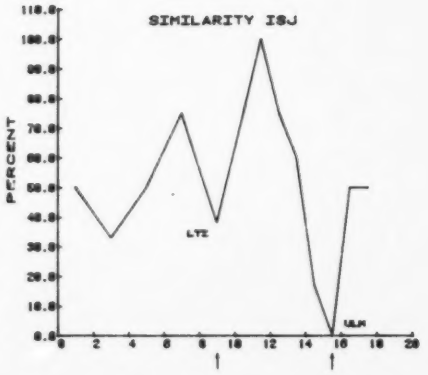


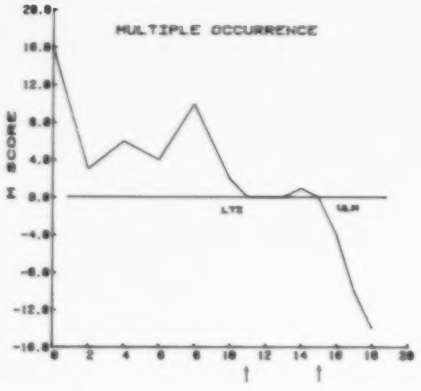


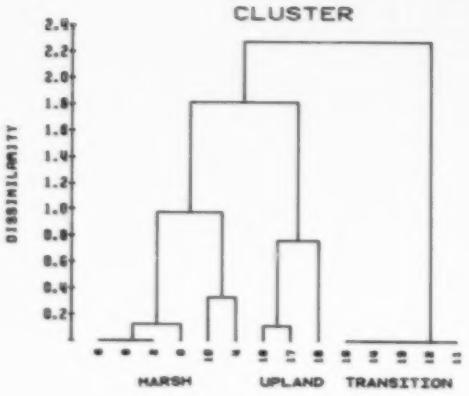
TRANSECT 0804

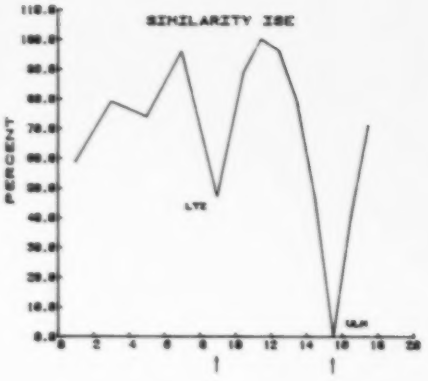




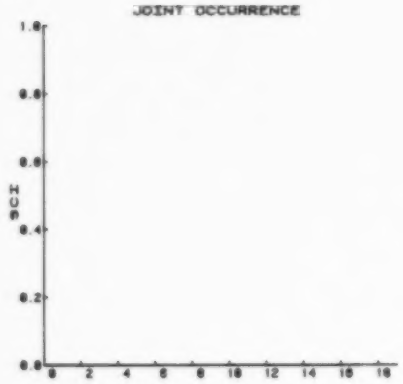


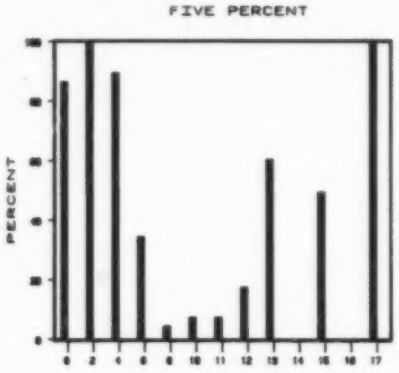


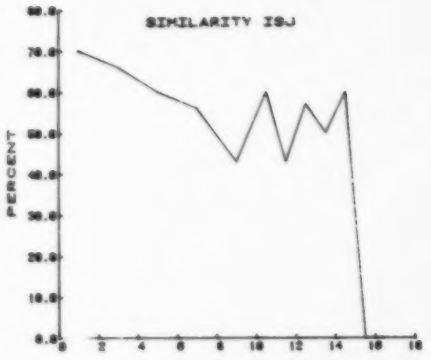


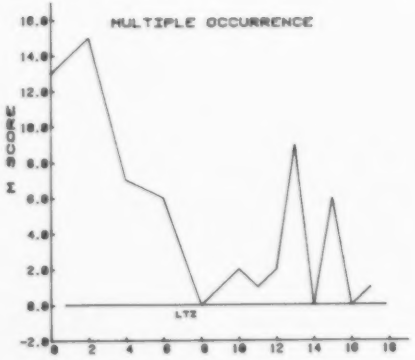


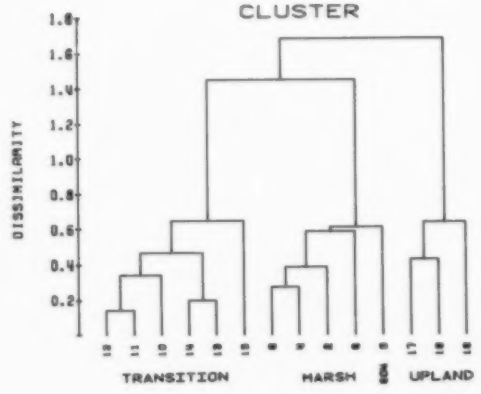
TRANSECT 0808

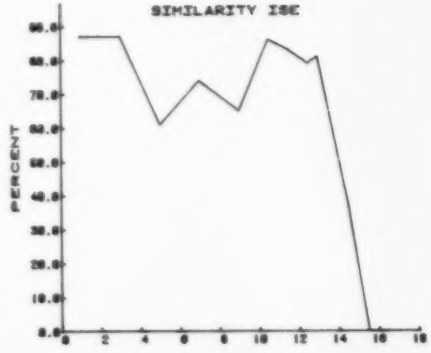




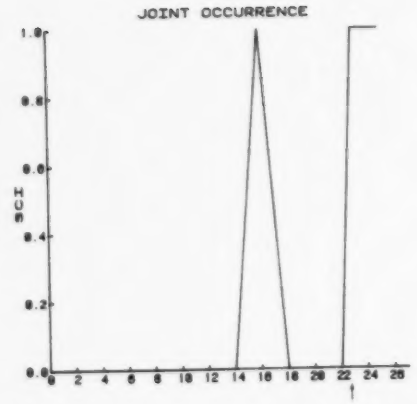


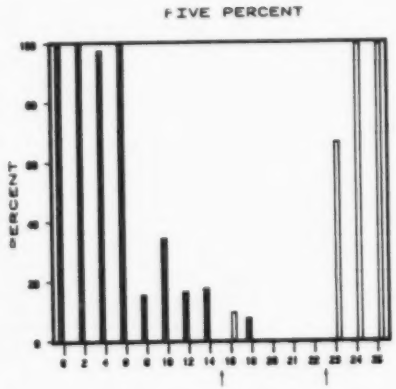


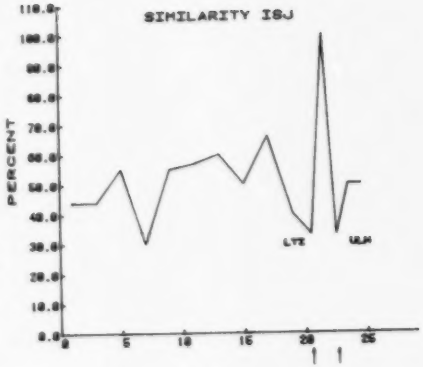


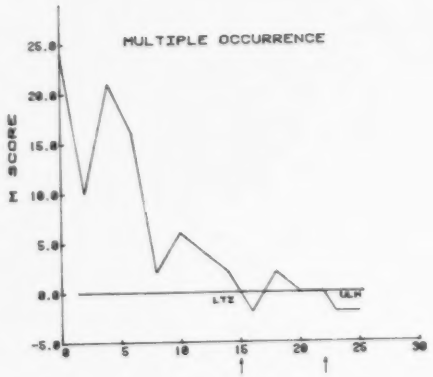


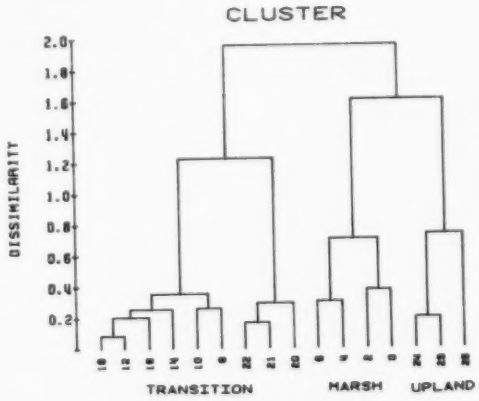
TRANSECT 0809

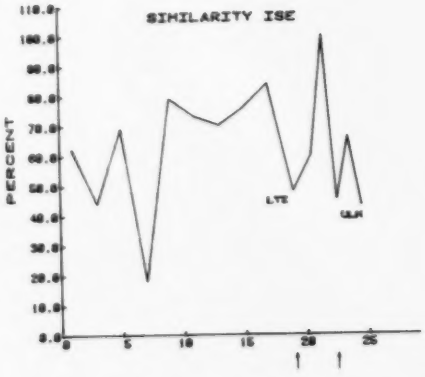




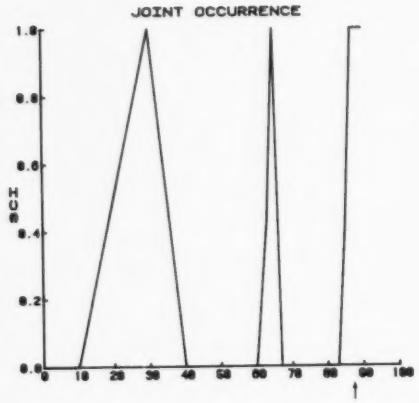


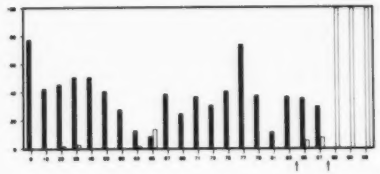


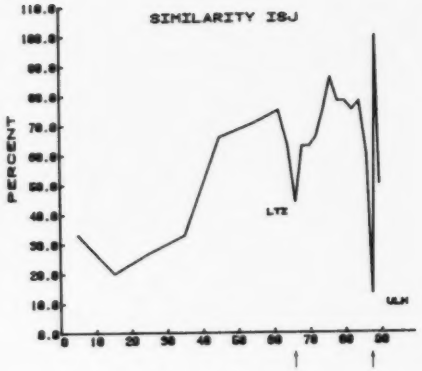


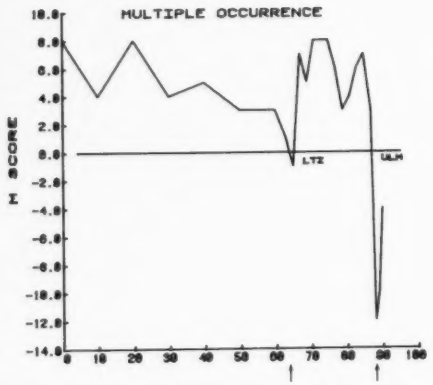


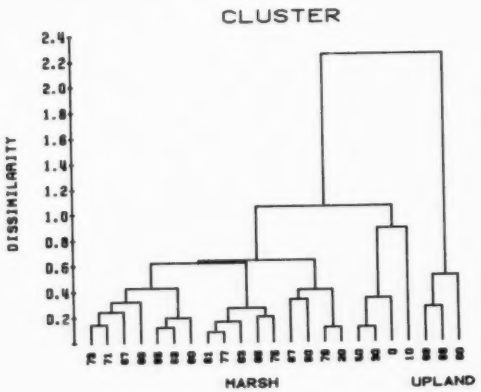
TRANSECT 0910

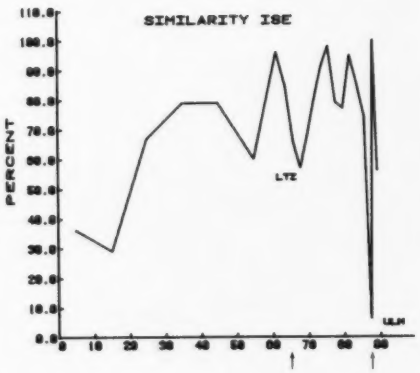




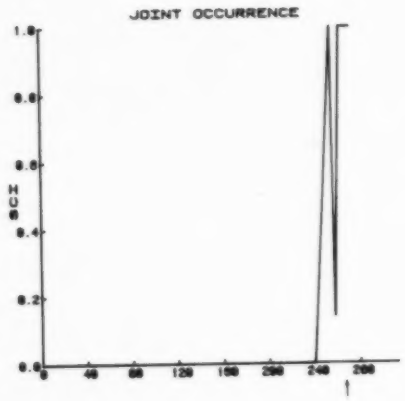


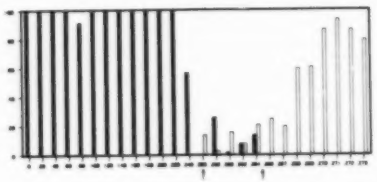


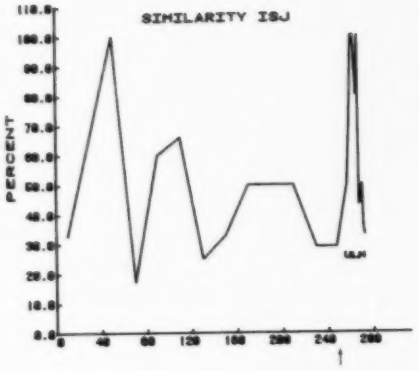


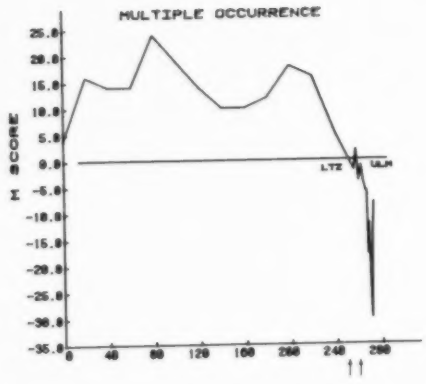


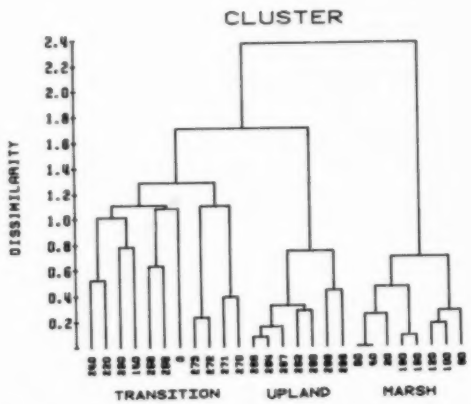
TRANSECT 1001

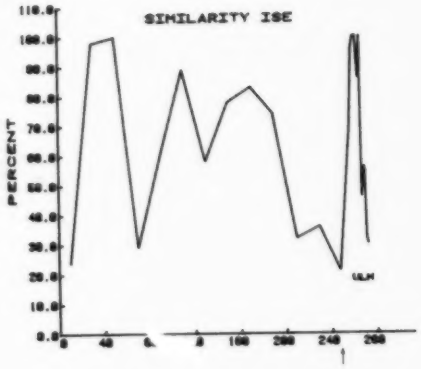




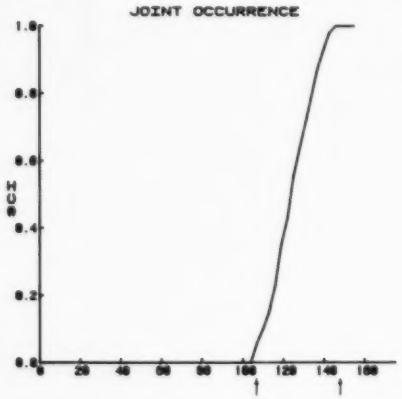


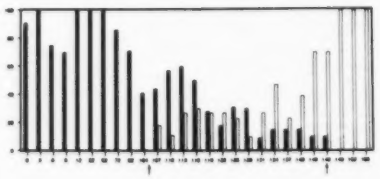


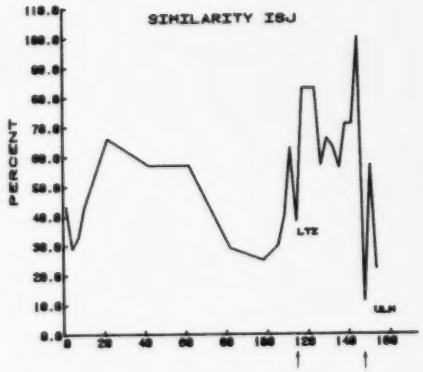


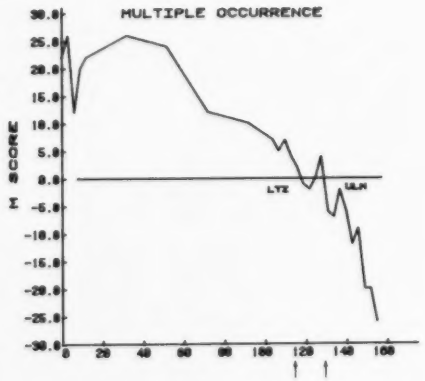


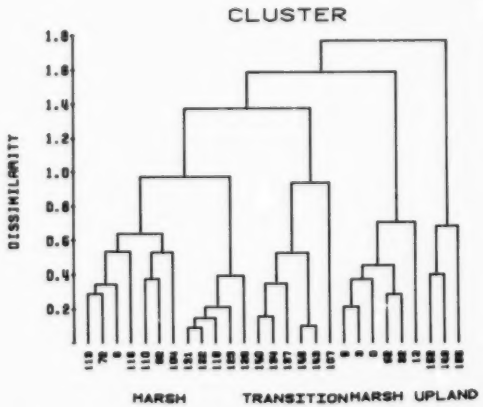
TRANSECT 1103

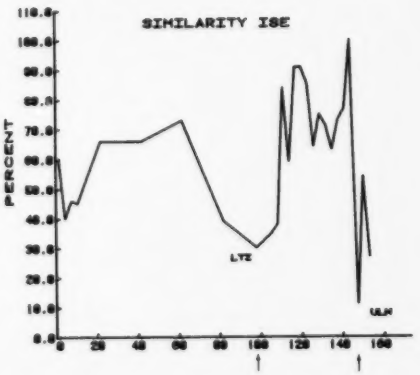




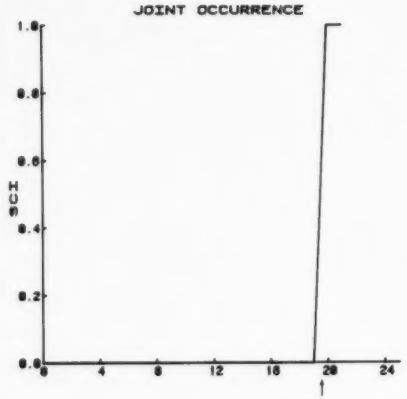


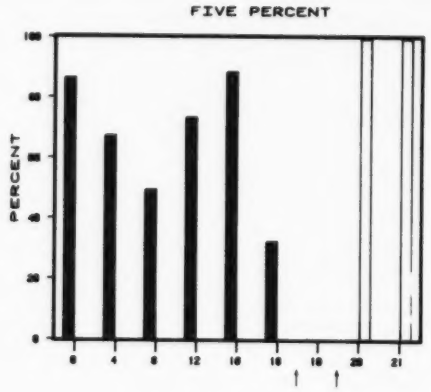


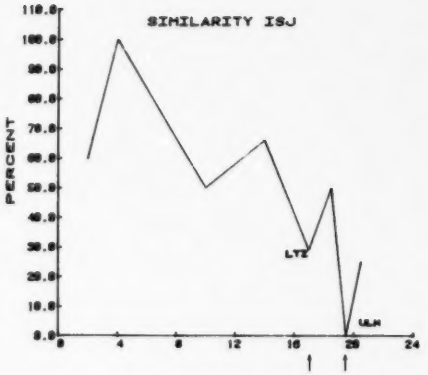


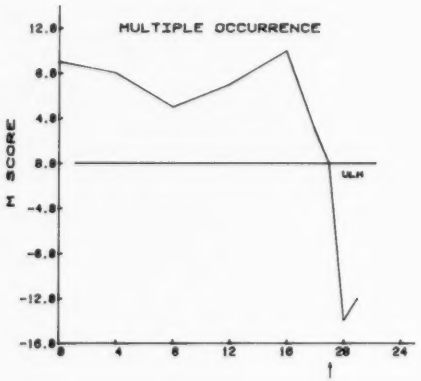


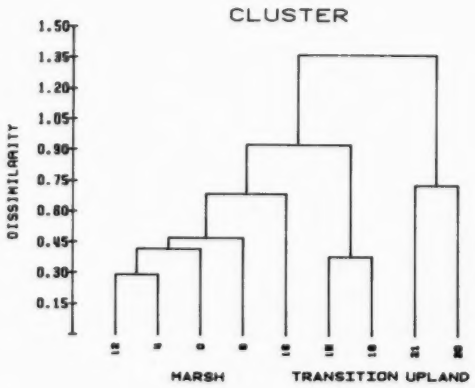
TRANSECT 1201

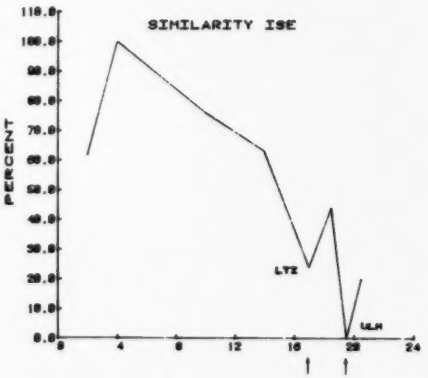




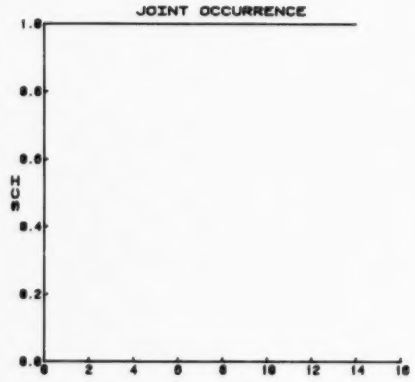


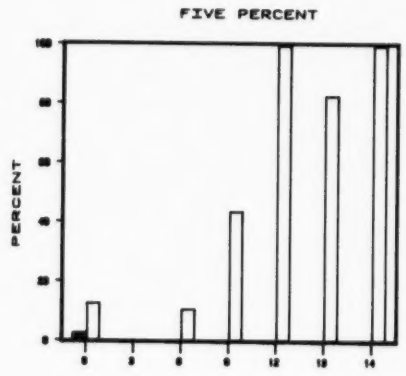


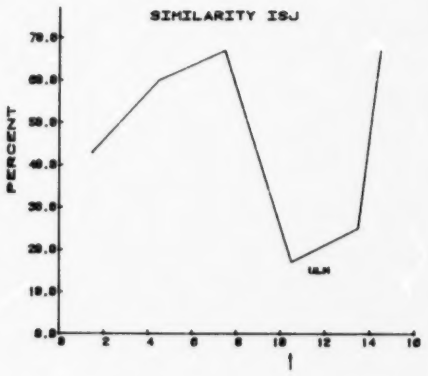


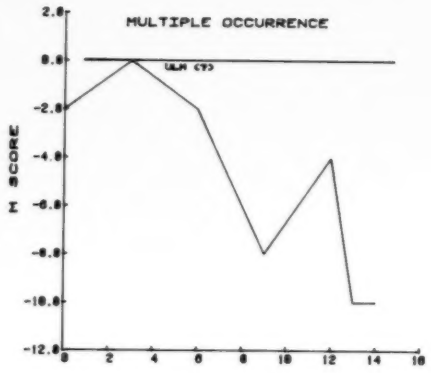


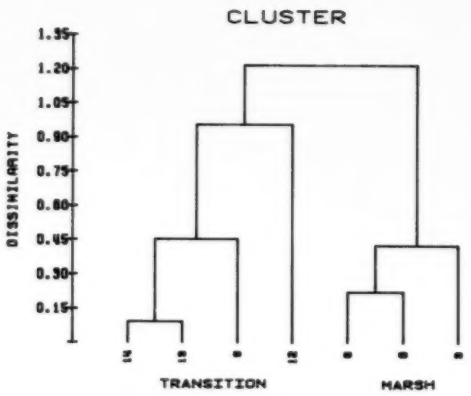
TRANSECT 1606

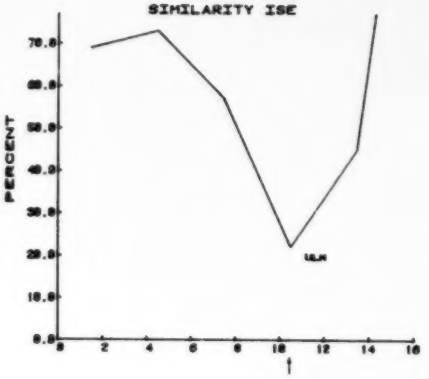




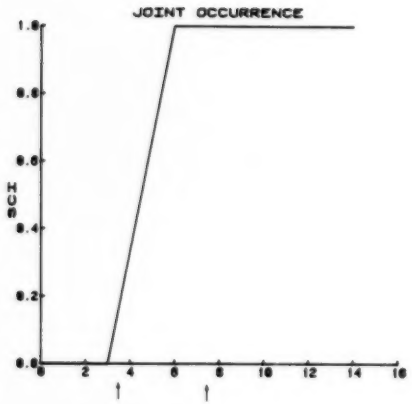


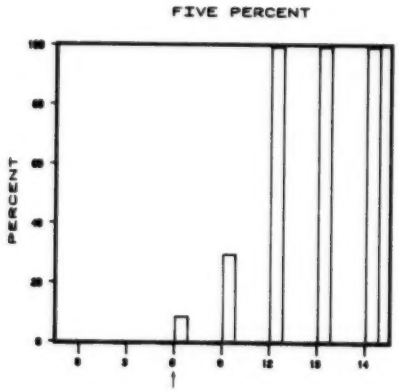


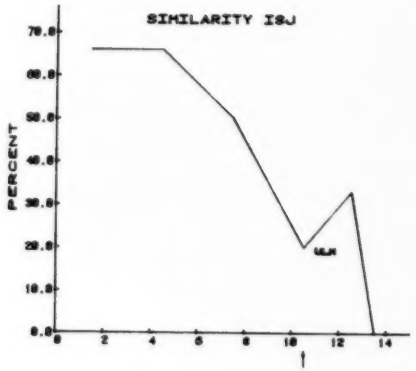


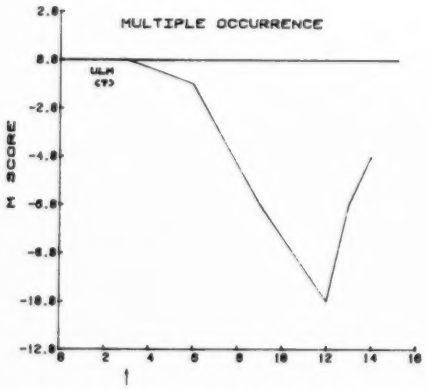


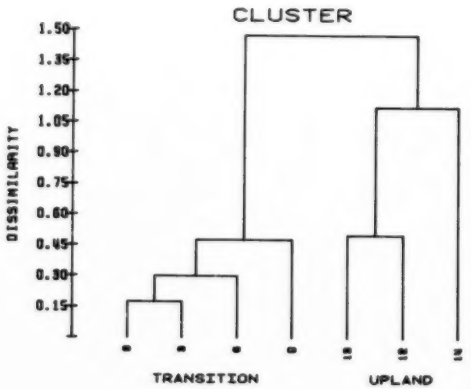
TRANSECT 1610

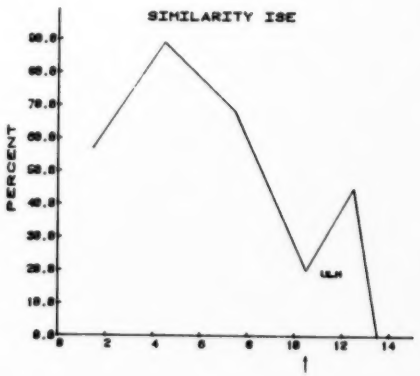




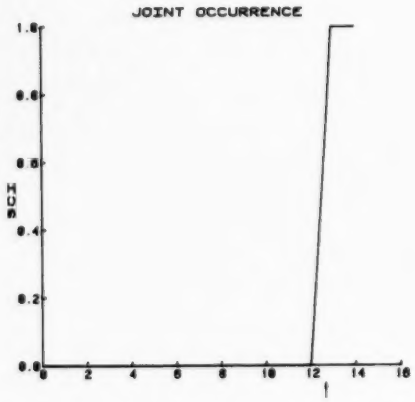


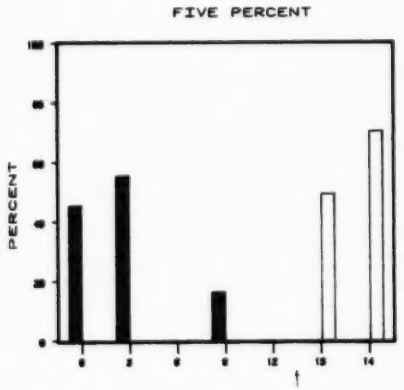


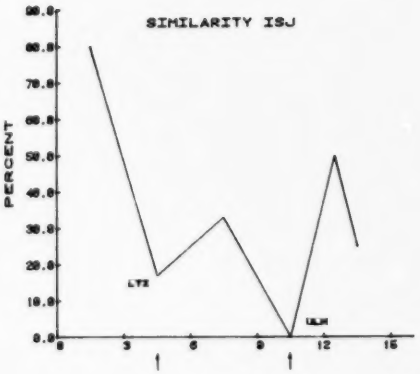


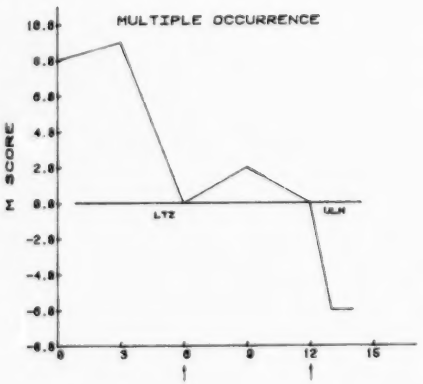


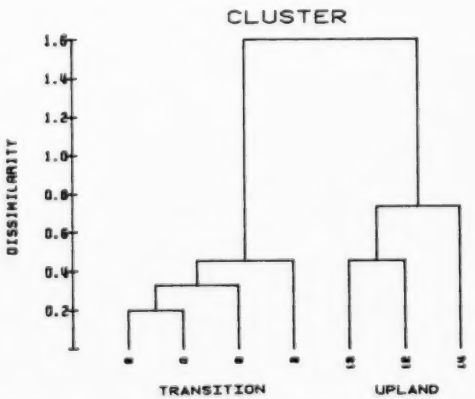
TRANSECT 1611

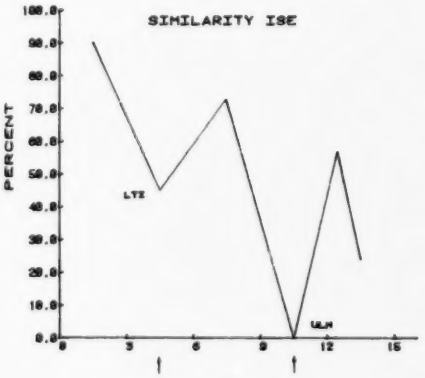




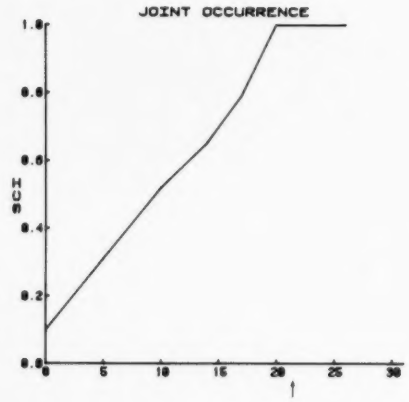


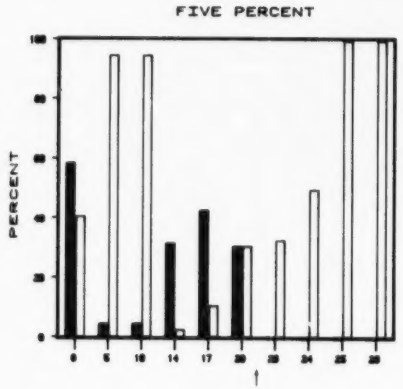


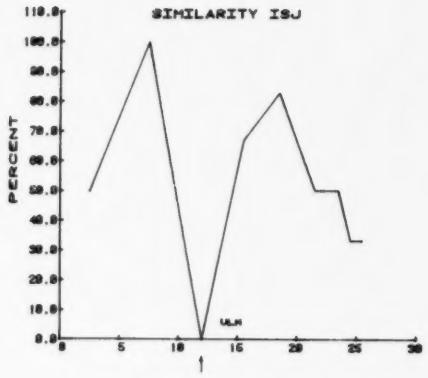


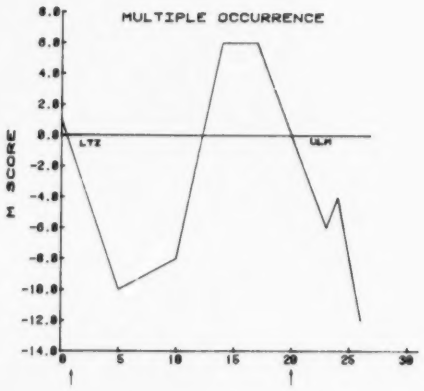


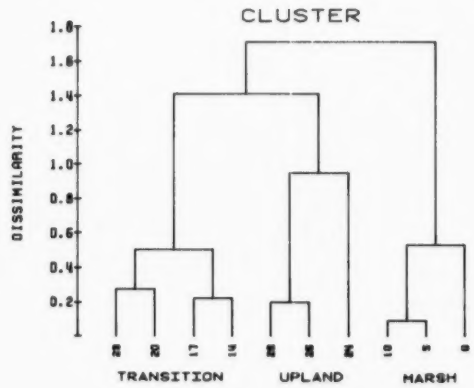
TRANSECT 1612

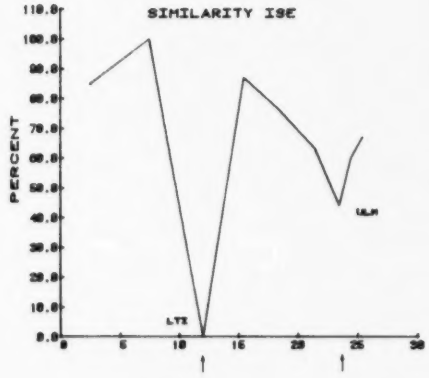




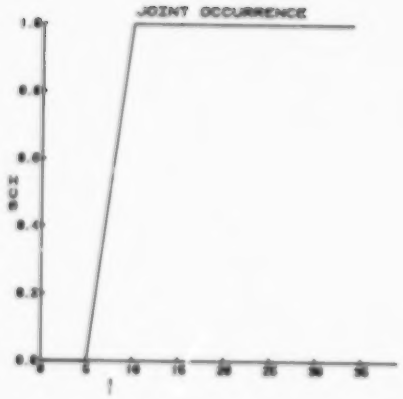


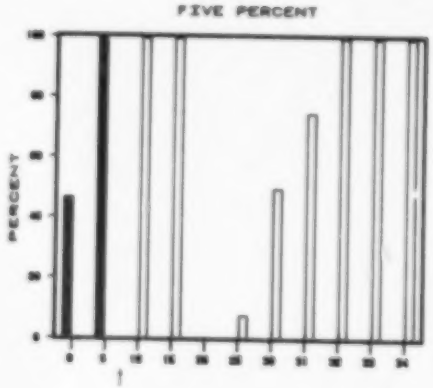


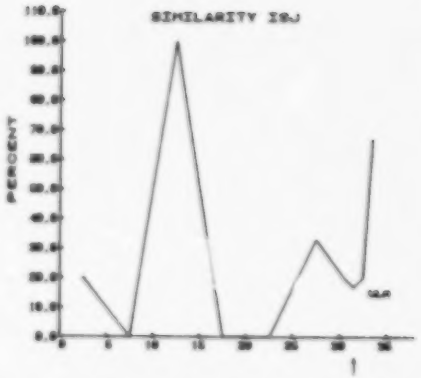


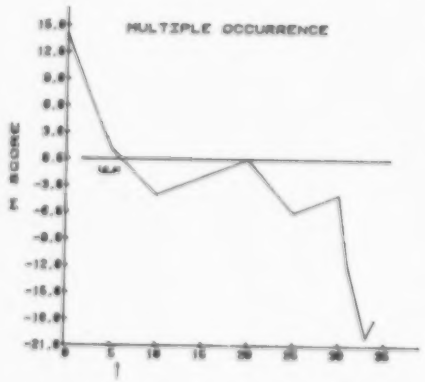


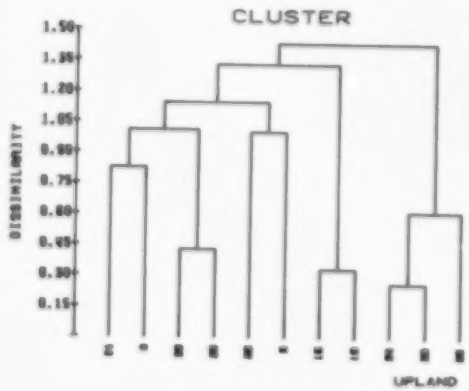
TRANSECT 1703

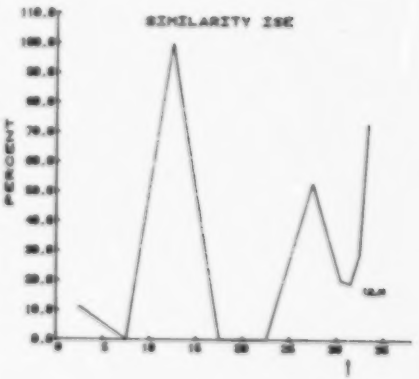




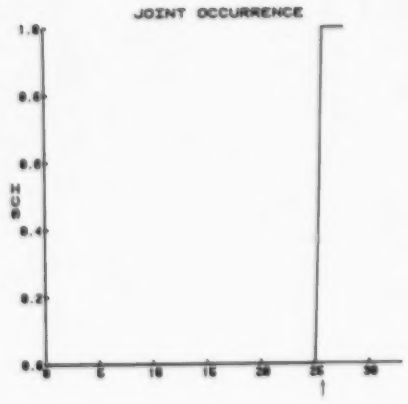


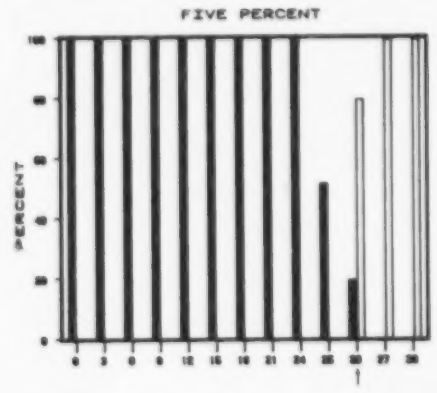


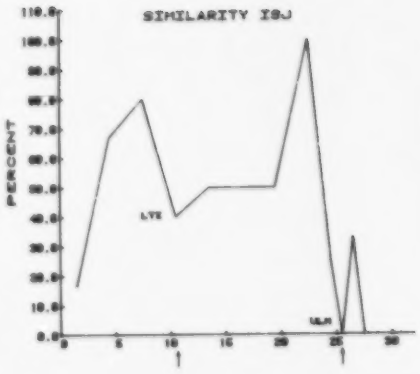


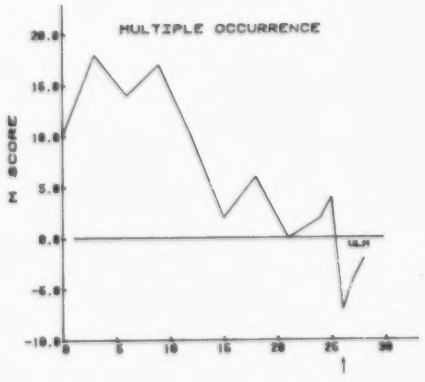


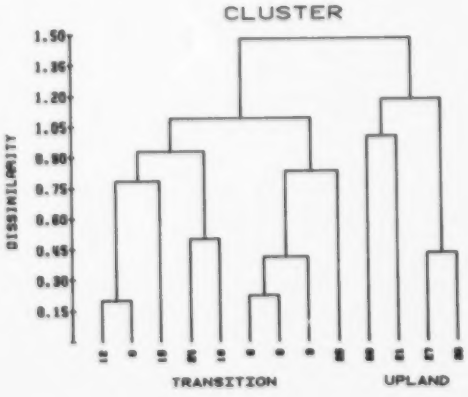
TRANSECT 1802

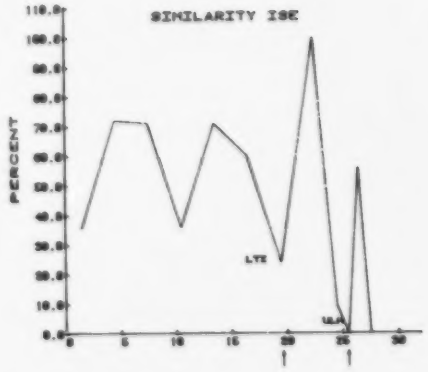












APPENDIX D

Sample Field Data Sheet

Wetland Name _____ Date _____

Plant Species	Quadrat (Labeled as distance along transect; 1 = wetland)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															

APPENDIX E

Computer Software Available at U.S. Environmental Protection Agency, Corvallis, Oregon

Computer programs are available at the Corvallis Environmental Research Laboratory, Corvallis, Oregon for the cluster, similarity ISJ and ISE, and joint occurrence methods. We are currently developing an additional program to process data by the multiple occurrence method. Contact Jo Oshiro, U.S. EPA/CERL, Corvallis, Oregon 97333 for further information.